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Direct Climate Markets: the Prospects for Trading Teleconnection Risk

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DIRECT CLIMATE MARKETS: THE PROSPECTS FOR TRADING TELECONNECTION RISK

DISSERTATION

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the College of Agriculture at the University of Kentucky

By
Grant Cavanaugh
Lexington, Kentucky

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Lexington, Kentucky 2013

ABSTRACT OF DISSERTATION

DIRECT CLIMATE MARKETS: THE PROSPECTS FOR TRADING TELECONNECTION RISK

This dissertation provides the analysis necessary to launch the first direct climate markets. Combining statistical modeling with qualitative interviews, I build off of an innovative insurance project to show why and how to start traded markets on indexes of El Niño/La Niña. I provide statistical models of El Niño/La Niña's worldwide economic impacts; a stochastic catalog used to price virtually any risk management contract on El Niño/La Niña, even as new forecasts change traders' expectations; a comprehensive statistical description of the lifecycle of new derivatives showing how the prospects for new derivatives changed fundamentally in the last decade (this work is co-authored by Michael Penick, Senior Economist at the US government's derivatives regulator, the Commodity Futures Trading Commission); and, interviews with risk management professionals at businesses facing El Niño/La Niña risk and financial firms interested in trading that risk. Based on this analysis, I conclude that catastrophe bonds settling on NOAA's Niño 3.4 sea surface temperatures can, and likely will, launch in the near future.

KEYWORDS: Climate, Economics, Risk Management, Insurance, Derivatives

Author's signature: Grant Cavanaugh

Date: August 2, 2013

DIRECT CLIMATE MARKETS: THE PROSPECTS FOR TRADING TELECONNECTION RISK

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Much of the research here came from my work at for GlobalAgRisk in Peru. The GlobalAgRisk team manages innovative projects across the globe and is the reason that I came to Kentucky. They are amazing people doing amazing work. Much of that work in Peru was sponsored by the Gates Foundation. The UN Development Programme and GIZ also contributed funding for my work on household-level El Niño protection.

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I conducted many interviews as part of this dissertation. I want to thank everyone who offered their time for those interviews.

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Chapter 1

Introduction: Direct Climate Markets

What are the major market indexes for climate change? Posed recently on the popular economics blog, Marginal Revolution, that question stumped blog co-author and George Mason professor of economics, Tyler Cowen (Cowen, 2013).

There are markets covering the policy response to climate change, like those on emissions permits. But as Dr. Cowen notes, those markets are about "...mitigation efforts, not the extent of warming or climate change per se." The EU's emissions-trading system (ETS), the legally binding system underpinning the largest carbon trading system on the planet, recently provided a jarring reminder of that distinction. On April 16, 2013 the European Parliament voted against proposals that would have altered the scheduled for issuing emissions permits under the ETS. That day, the price of EU carbon permits fell 40 percent (The Economist, 2013b). Nothing about the long-term prospects for earth's climate changed 40 percent that afternoon.

When Dr. Cowen turned the question over to his blog's readers their suggestions fell into two categories:

1. pure climate indexes, like the extent of Arctic ice; and,
2. indexes of businesses with some climate risk, like the stock price of reinsurance companies.

Neither type of index offers a strong foundation for at actively traded risk markets directly linked to climate. The climate indexes are unlikely to trade - they are long-term indicators only moving gradually and translate poorly into the perceivable business risks that attract active trading. The business indexes have only loose links to climate - the stock price of a reinsurer, for example, is determined as much by their investing returns as by their climate linked losses.

This dissertation provides the analysis necessary to launch the first direct climate markets. Combining statistical modeling with qualitative interviews, I build off of an innovative insurance project to show why and how to start traded markets on indexes of El Niño/La Niña risk. I provide:

- statistical models of El Niño/La Niña's worldwide economic impacts;
- a stochastic catalog used to price virtually any risk management contract on El Niño/La Niña, even as new forecasts change traders' expectations;
- a comprehensive statistical description of the lifecycle of new derivatives showing how the prospects for new derivatives changed fundamentally in the last decade[1]; and,

[1]This chapter is co-authored by Michael Penick, Senior Economist at the US government's derivatives regulator, the Commodity Futures Trading Commission

- interviews with risk management professionals at businesses facing El Niño/La Niña risk and financial firms interested in trading that risk.

Based on this analysis, I conclude that catastrophe bonds settling on NOAA's Niño 3.4 sea surface temperatures can, and likely will, launch in the near future.

More than just protecting us against catastrophic events, markets on El Niño/La Niña and related phenomenon will bridge the gap between climate, a process that unfolds over decades or centuries, and weather as we live it. To the extent that we see climate change's effects year to year, they generally appear as changes in what climate scientists call *teleconnections*, phenomena like El Niño/La Niña that have wide-ranging impacts across the globe. With the influence of climate change visible in recent time series of major teleconnections (see chapters 3 and 11) these markets may also provide a consensus forecast of climate change's impacts on weather in the near term.

1.1 The innovative insurance behind this dissertation

In 2011, I was part of a team that helped Caja Nuestra Gente, a large microfinance bank in Peru, purchase the world's first insurance against the El Niño climate phenomenon. We designed the insurance policy to protect the bank's loan portfolio against defaults after catastrophic El Niño flooding. In 1998, El Niño flooding left many banks in the country's impoverished northern provinces with inadequate capital. That meant that banks could not originate the new loans needed to rebuild hurting communities, a feedback loop repeated on a global scale in the 2007/2008 Financial Crisis.

The insurance policy we drafted moved part of the bank's El Niño risk to a large international reinsurance company. Thanks to that risk protection, the bank now plans to continue lending to affected communities when credit is most urgently needed - during the recovery and reconstruction following El Niño.

The team responsible for that insurance came from a research firm, GlobalAgRisk[2], led by University of Kentucky professor, Jerry Skees. GlobalAgRisk and its sponsor, the Gates Foundation, initially focused on El Niño because the phenomenon caused catastrophic flooding in a part of Peru with a particularly high incidence of poverty. [3]

In strong El Niño years, a plume of warm air (coming off a relatively warm ocean) meets cold air, rolling down the Andes Mountains. That causes prolonged periods of extreme rainfall over a region that looks like a desert in normal years. Figure 1.1 shows that the most recent severe El Niño events, in 1982/83 and 1997/98, caused annual precipitation on the order of 40 times average. More dramatically, over two weeks in 1998, a lake, second only in size to Lake Titicaca in Peru, formed spontaneously in the desert south of Piura (a regional capital that was the center of our work). These events caused devastating personal and economic hardship. Some 200,000 people were

[2] `globalagrisk.com`

[3] Southern Ecuador was similarly impacted by terrible flooding.

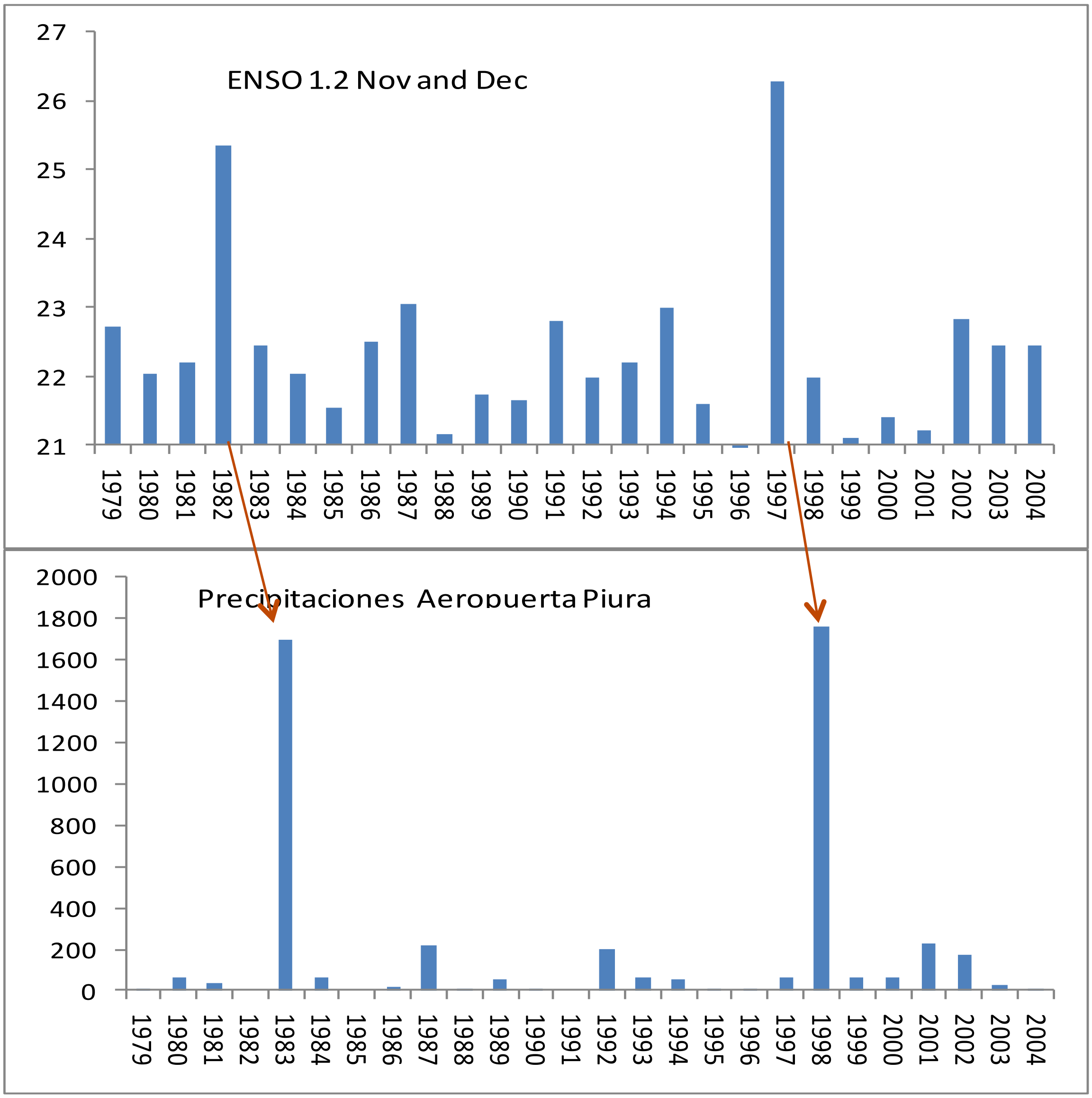


Figure 1.1: Precipitation measured at Piura Airport and Niño SST index (from Mario Miranda and Jerry Skees)

displaced from their homes, the second largest port in the country was shut down, and the regional economy ground to a halt (Suplee, 1999).

Our insurance addresses a fundamental social need and is a true financial innovation. Payment is trigged solely by the sea-surface temperature (SST) rise that defines El Niño, measured by the US's National Oceanic and Atmospheric Administration (NOAA) over defined regions off the coast of Peru. (See figure 3.4 for a map of the different regions where NOAA measures El Niño-related SSTs). Sharp rises in that temperature, particularly in the months of November through January[4], define the El Niño phenomenon and *cause* catastrophic flooding in Peru (Khalil et al., 2007).

Our insurance pays out exclusively based on that *causal* temperature signal which precedes Peruvian flooding by months. That lag gave us the chance to create, we believe, *the first regulated insurance in history that pays before a disaster.* The temperature measure that triggers payment is posted on NOAA's website in early January, so the insurance company can send its clients checks before they are affected by floods between late January and April.

1.2 From insurance to direct climate markets

In the course of working on that insurance, my colleagues at GlobalAgRisk and I learned a fair bit about El Niño-Southern Oscillation (ENSO), the full cycle of changing oceanic and atmospheric patterns that includes El Niño (warm SST anomalies) and La Niña (cold SST anomalies). ENSO is one of a handful of regional climate phenomena that drive patterns of catastrophic weather across the globe. As we worked with businesses and insurance companies to model their ENSO risk, we began to suspect that the financial importance of ENSO and its closest climatic cousins, like the Arctic Oscillation, could extend far beyond our humble experiment in Peru.

Teleconnections are statistical and physical links between regional oceanic/atmospheric anomalies, such as ENSO and the Arctic Oscillation (AO), and patterns of catastrophic weather around the world. Teleconnections are excellent candidates to be the basis of insurance or derivatives thanks to the scope and diversity of their impacts, the predictive nature of the signals they generate, and the fact that they can be represented by simple indexes published by trusted national meteorological services (NMS), such as NOAA in the United States.

This dissertation explores the idea that traded markets based on these teleconnection indexes could provide a low-cost risk management tool to firms, individuals, and institutions facing catastrophic weather risk. They would also provide consensus forecasts on weather-related catastrophe risk. ENSO appears to be the lowest hanging fruit among the teleconnections, the one phenomenon from the group that is already a target for insurance. For that reason, most of this dissertation is devoted to ENSO. But ENSO, should it succeed, may be followed by others like the Arctic Oscillation, which I discuss in chapter 11.

However, all these benefits are predicated on liquidity - high and stable trading activity. The market will only provide reliable forecasts if climate scientists spend

[4]See figure 3.1 for more detail on the typical El Niño calendar

time watching for changes in prices that are not justified by the current state of the climate. Individual climate scientists and the financial firms who might hire them will only dedicate the resources to watch for these mispricings if they believe that they can make profits when they catch a temporary mispricing. That is difficult when a market is small, either because there is no one to take the other side of the trade or because the few people who would take the trade can infer from a large order that they can demand a better price. As I show in chapter 6, a collaborative effort with Michael Penick of the US Commodity Futures Trading Commission(CFTC)[5], the history of financial innovation is littered with good ideas for markets that never attracted liquidity.

More than just the idea of teleconnections markets, this dissertation looks at liquidity. Can teleconnection markets generate it? Under what conditions? I've devoted the last few years to researching these questions, putting special emphasis on ENSO. Throughout that time, I've tried to balance my personal enthusiasm with the skepticism of an empirical researcher. I've asked questions that I believe skeptics would ask, tackled them with rigorous quantitative methods, and set to explain the results as simply as possible. My results are cautiously optimistic on the prospects for ENSO markets in the near future.

1.3 Why hedge?

Before I dive into ENSO markets, I want to point out an assumption that runs throughout my research. During most of my dissertation, I assume that it is economically efficient for businesses, firms, and institutions to hedge catastrophic weather risks. I've already suggested, for example, that there is social value to Peruvian banks insuring against El Niño losses. That assumption might seem reasonable, even obvious, to non-economists. However, it is rejected by many well-respected economic models. So, before diving into my analysis of ENSO and teleconnections, it's worth reviewing exactly why I believe hedges against catastrophic weather risk are economically efficient.

Why you should not hedge

Markowitz (1952) founded the field of modern portfolio theory. Among this groundbreaking paper's implications was the idea that investors can diversify away the risks of individual firms and so their portfolio decisions should be made purely on the basis of undiversifiable market-wide risks. One implication of this idea, which contributed to Franco Modigliani's 1985 Nobel Prize, was that rather than insist that individual businesses hedge their risks, investors could achieve the same protection simply by holding a diversified basket of assets Modigliani and Miller (1959). If the best diversification that an individual business can hope to achieve is the diversification of holding a small slice of the economy as a whole, and an investor can achieve that same diversification by holding shares of many businesses, then businesses should not

[5]The CFTC regulates US derivatives trading.

bother to hedge. The businesses will generally have to pay for their hedges, while investors will receive the same protection just by spreading out their capital.

Indeed, that reasoning has far reaching impacts on the real economy. Exxon Mobile, the largest firm on the planet by 2013 revenues, is a testament to modern portfolio theory (DeCarlo, 2013). John Parsons and Antonio Mello professors of corporate risk management at MIT and University of Wisconsin explain in a blog post (Parsons and Mello, 2011):

> Exxon doesn't use derivatives. At least not many of them. This is in strong contrast with a number of other oil majors that make active use of derivatives-for example, BP and Shell.
>
> This fact is a real puzzle for those who argue that companies should use derivatives to hedge the financial risks coming from their physical business.

Parsons and Mello suggest that what they call "the Exxon Puzzle" might be solved if the company used physical investments to generate the derivatives-like hedges. But another possibility is simply that Exxon is large enough to provide sector-wide exposure to energy and that they believe that shareholders could and should provide any additional risk management through their own portfolio management in the fashion of Modigliani and Miller (1959).

Why you should hedge

But, Parsons and Mello remain puzzled by Exxon's reluctance to hedge because the firm's behavior contrasts with a large body of literature showing empirically how hedging adds value to firms. Indeed, our best evidence is that firm-level hedges are valuable throughout the economy. Allayannis and Weston (2001) looked at 720 large non financial firms between 1990 and 1995 and found that foreign currency hedging had a statistically significant correlation to firm value, increasing that value of at-risk firms by an average of 4.87 percent. That estimate sits close to the center of a range established by subsequent studies. Within the US airline industry, that *hedging premium* might be as high as 10 percent according to Carter, Rogers, and Simkins (2006). Berrospide, Purnanandam, and Rajan (2008) places the premium for Brazilian firms using foreign currency hedges between 6.7 and 7.8 percent. Mackay and Moeller (2007) estimated the effect for oil refineries to be between 2 and 3 percent. Graham and Rogers (2002) restricts itself to the tax benefits of hedging and finds that the increased debt capacity afforded to hedged firms results in increased tax benefits equaling 1.1 percent of firm value for the average hedging firm across a three thousand firm sample.

That empirical work builds on academic literature illustrating the theoretical value of hedging in the presence of economic frictions like asymmetric information and taxes. Froot, Scharfstein, and Stein (1993) shows how risk management puts firms in a position to take advantage of attractive investment opportunities. Smith and Stulz (1985) and Leland (1998) focuses on the tax implications of hedging. Stulz (1984) and

Mayers and Smith Jr (1982) show how incentives within ownership and management might favor hedging.

The empirical evidence most relevant to this dissertation comes from Pérez-González and Yun (forthcoming), which looks directly at the effects of the introduction of weather derivatives on US energy firms. The authors believe that the impact of hedging on firm value is as high as 20 percent, although they "cannot reject that the causal effect of risk-management on market-to-book ratios is in the 5 to 10 percent level, as previously reported in the literature." Pérez-González and Yun (forthcoming) also shows that among firms with substantial weather exposure:

> hedging allows [for] increased investment and... aggressive financing policies. Such results are consistent with the idea that smooth cash flows allow firms to invest more, either by relaxing borrowing constraints or by allowing firms to pursue valuable investment projects in low cash flow states. Similarly, they provide evidence that left-tail cash flow realizations can limit debt capacity due to distress costs or other frictions.

Exxon seems to take the arguments against hedging seriously. But in spite of Exxon's strategy, there is a substantial body of literature, covering many firms in many industries, that shows how hedging provides an economically meaningful, and statistically significant, boost to firm value. Hedging large business risks, particularly climate risks, is economically efficient. As I show in chapters 3 and 8, ENSO is certainly among those large business risks deserving its own hedging.

1.4 Dissertation road map

I've broken my overarching questions about ENSO liquidity into a series of smaller research projects. I've tried to assemble and explain these projects in such a way that it is accessible not only to academics, but to financial professionals as well.[6]

With that in mind, I start with a discussion of risk of El Niño/La Niña itself:

> *What are the economic impacts of El Niño/La Niña? Why is El Niño/La Niña risk a good candidate to move to financial markets?*

In the Estimating Disaster Damages chapter (chapter 2), I introduce the dataset that I used to estimate El Niño/La Niña's economic cost. In its raw form, that dataset is substantial. But, in my opinion, it is insufficient to provide a comprehensive picture of teleconnection impacts. To address that shortcoming, I infer missing data using Bayesian regressions. The Estimating Disaster Damages chapter explains how and why I made that inference.

The El Niño-Southern Oscillation (ENSO) chapter (chapter 3) gets to the heart of ENSO's economic impacts. It presents a brief overview of the ENSO cycle and my

[6] Beck (2013) has an excellent visualization of dissertation lengths by discipline, reproduced in the Appendix C: Miscellaneous as figure 16. Unfortunately for my committee, mine is objectively long.

estimates, based on the enhanced database from chapter 2, of its economic cost in vulnerable regions. The chapter shows that:

1. ENSO risk is large enough in absolute terms to justify formal risk markets;

2. large pools of ENSO risk offset one another in time and space, suggesting that ENSO markets could sustain balanced, direct trading among hedgers; and

3. ENSO creates a pool of economic risk that is comparable to those underlying some large futures markets today.

To conclude Part I, the Pricing ENSO Derivatives chapter (chapter 4) presents my analysis of the probability of extreme El Niño/La Niña events. I use those probabilities to price various financial risk management instruments including insurance, options, and futures. This chapter includes models of how the likelihood of El Niño/La Niña events changes over time, as meteorologists release new ENSO forecasts. The chapter is supported by appendixes Appendix D: January Pricing through Appendix O: December Pricing, showing pricing distributions for calls and puts on ENSO, throughout the year, conditioned on consensus forecasts. This chapter provides would-be market makers in ENSO risk with a starting point for the spreads they set and hedgers with a baseline for identifying a well-priced hedge.

The second half of the dissertation focuses on ENSO as the basis of a market:

> *In what form ((re)insurance, futures, options, swaps, etc.) will El Niño/La Niña markets be most likely to reach a sustainable level of liquidity? What form offers institutions, firms, and individuals the most efficient tool for managing their risk?*

In the Why Futures and Options? chapter (chapter 5), I provide basic information about the forms that an El Niño/La Niña risk market could take. I also discuss my initial hypothesis that exchange-traded derivatives (futures and options) provide the most efficient and equitable avenue for managing ENSO risk. This chapter is not original research, but an overview of what I consider the prerequisites for efficient social outcomes from teleconnections markets.

> *Having identified exchange-traded derivatives markets as a promising avenue for teleconnection risk, the next logical question is what is the baseline probability that any new cleared/exchange-traded derivative will succeed or fail?*

In the The Lifecycle of Derivatives Contracts chapter (chapter 6), a collaborative effort with the Senior CFTC Economist, Michael Penick, I test my hypothesis about futures and options by looking at the probability that any new exchange-traded derivative will succeed. That analysis is based on a comprehensive database covering all derivatives traded on US exchanges since the mid-1950s. I show how the lifecycle of derivatives has changed over time, and what that means for innovative markets. The picture emerging from that analysis is moderately hopeful for ENSO. The probability of reaching very great liquidity was never high, and has fallen over time. However, the probability of reaching modest levels of liquidity and the probability of recovering from years with very little trading have improved remarkably in the last decade.

I finish my analysis in the Interviews With Risk Professionals and Willingness-to-pay for ENSO Risk Protection chapters (chapters 8 and 9), by asking risk professionals, who might be early adopters of ENSO risk management instruments, for their thoughts on the likely demand and supply of ENSO risk management and the form that those markets should take. The Interviews With Risk Professionals chapter provides qualitative analysis from more than 35 in-person interviews around the world. Many of those interviews focused on the current state of catastrophe and weather risk trading so I've include a short introduction to those markets in Traded Catastrophe and Weather Markets Today.

These interviews forced me to reconsider my initial hypothesis about futures and options. While I continue to believe that futures and options remain an important end-goal for ENSO markets, my interview subjects persuaded me that those exchange-traded markets will have a better chance at success if they evolve from catastrophe bond (CAT bond) trading.

Chapter 8 includes the proposal of one interview subject, John Seo of Fermat Capital, of a liquidity fund that will help smaller investors access customized coverage from CAT bond markets, generally reserved for institutional investors. This liquidity fund would achieve the desirable social outcomes associated with exchange-trading within the context of the CAT bond markets that industry professionals prefer. That fund would operate at no net cost to its host institution.

The Willingness-to-pay for ENSO Risk Protection chapter provides quantitative validation of the interview findings. It includes an adaptive choice-based conjoint analysis of 15 experts willingness to pay for various contract designs.

After some concluding remarks on the solid prospects for ENSO markets the Arctic Oscillation (AO) chapter (chapter 11) provides an epilogue to this dissertation. That chapter introduces the Arctic Oscillations, the teleconnection that I consider the next frontier for formal risk management after ENSO.

Chapter 2

Estimating Disaster Damages

The first step in scoping teleconnections markets involves estimating the economic damages associated with target indexes. That estimation requires a large database of disaster damage statistics. Unfortunately, many of the leading disaster databases are missing substantial data. So, before turning to ENSO in chapter 3, this chapter presents:

- a statistical process using country-level statistics from the World Bank to supplement the EM-DAT disaster statistics database; and
- analysis of the quality of that statistical process through cross-validation.

2.1 EM-DAT database

The three databases most popular for academic disaster research are, the Emergency Events Database (EM-DAT) maintained by Center for Research on the Epidemiology of Disasters in Brussels, NatCat maintained by the reinsurance company MunichRe, and Sigma by the reinsurer SwissRe. EM-DAT, the database I use here, offers fewer recent records than NatCat, the largest of the three at roughly $15,000$ entries. But it has more complete historical records and is easily accessible to researchers (Guha-Sapir and Below, 2002). Established as resource for epidemiological studies, and supported by the United Nation's World Health Organization (WHO) and the Belgian Government, EM-DAT is the database that academics have used most often to estimate ENSO related damages (Bouma et al., 1997) (Goddard and Dilley, 2005).

EM-DAT contains data on roughly 12,000 natural disasters from 1900 to present. Each disaster in the database contains some combination of the following information:

- Country: Country(ies) in which the disaster has occurred.
- Disaster type: Description of the disaster according to a pre-defined classification.
- Date: The date when the disaster occurred.
- Killed: Persons confirmed as dead, missing, and presumed dead.
- Total affected: A sum including:

  Injured: People suffering from physical injuries, trauma or an illness requiring medical treatment as a direct result of a disaster.

  Homeless: People needing immediate assistance for shelter.

  Affected: People requiring immediate assistance during a period of emergency; it can also include displaced or evacuated people.

- Estimated Damage: Several institutions have developed methodologies to quantify these losses. However, there is no standard procedure for determining losses. Estimated damages are given in million USD current to the reporting of the disaster.

Those data points are compiled from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies. For a disaster to be entered into the database it must fulfill at least one of the following conditions:

- Ten or more people reported killed.
- Hundred or more people reported affected.
- Declaration of a state of emergency.
- Call for international assistance.

EM-DAT is large enough to provide a solid foundation for investigating the consequences of regional climate anomalies. But the database suffers from some glaring omissions. For example, the northern Peruvian state of Piura was the epicenter of flooding during the 1997/1998 El Niño. As noted earlier, an estimated 200,000 people were affect by that flooding. However, the EM-DAT database registers the greatest El Niño in the modern era as only an outbreak of disease in Piura and flooding in nearby Ecuador. For that reason, I supplement the EM-DAT statistics with regressions to fill in missing data in this chapter. I also use informative Bayesian priors on impact parameters in chapters 3 and 11.

Supplemental data sources and initial exploratory analysis

EM-DAT includes roughly 11,000 disasters dated between 1960 and 2010. Of those 11,000 entries, most included estimates of the people killed and affected[1], but only 32 percent included estimates of economic damages. I randomly selected 75 percent of those roughly 3,600 disasters with damage estimates as the training set for a Bayesian regression that would extend expected damage estimates to all disasters in the sample, a process called bootstrapping in statistics.

EM-DAT gives disaster estimates in terms of USD current to the disaster's reporting (i.e. generally in the year that the disaster occurred.) Using a base month of June 2010, I adjusted those economic damage estimates in the database values for inflation. Inflation estimates came from the U.S. Department of Labor's Bureau of Labor Statistics via the Federal Reserve Bank of St. Louis' FRED database (Federal Reserve Bank of St. Louis, 2012).

Once the sample's damage estimates were in comparable units, I added in the World Bank and IMF estimates in 2010 US dollars of the GDP per capita in the

[1] I supplemented the entries missing estimates of the numbers affected or killed with the median value for that disaster type.

country-year of each disaster (The World Bank Group, 2012). Figure 2.1 shows a scatter plot of disasters in EM-DAT with official damage estimates plotted against the annual GDP per capita.

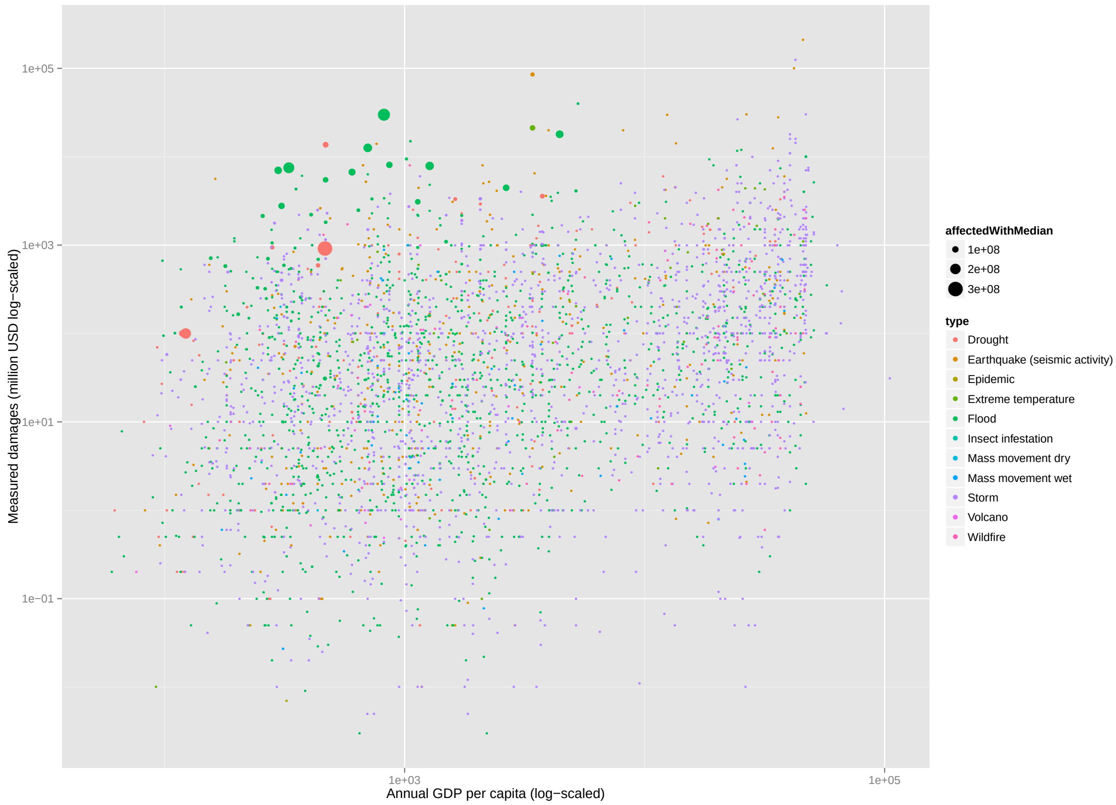


Figure 2.1: Scatter plot of available disaster damage estimates from EM-DAT database. The disaster type is indicated by the color of the point. The number of individuals affected is indicated by the diameter of the point. In this figure, the median number affected for that disaster type filled in for missing estimates of the number affected.

Figure 2.1 shows a small cluster of major disasters impacting populous and relatively poor counties. These are represented by the large dots in upper left quadrant of the figure. These are mostly major floods in India, China, and Bangladesh. While they caused some of the largest losses in the database, they affected orders of magnitude more people than other expensive disasters. In other words, the ratio between the human and measured economic tolls of these disasters was distinct from the others in the sample. The regression is most revealing when there is a stable relationship between economic damage and the combination of people affected and country-year GDP per capita. To achieve this, I separated this cluster of events from the rest of the sample and estimated the same regression on just that outlier sub-sample.

To identify this cluster of observations, I ranked all disasters by their ratio of affected individuals (including median estimates where no others were available) to the log of their GDP per capita in the country-year where they occurred. I separated

Table 2.1: Number of disasters in each data subset

	Training set	Cross-validation set	Prediction set	Total
Basic set	2646	862	7680	11188
High affected:GDP/capita	110	44	73	227
Total	2756	906	7753	11415

out observations with high ratios of the people affected to log GDP per capita, those with ratios at or above the sample's 98th percentile.

Apart from segregating that cluster of events into its own regression, my other data cleaning procedures were of minor importance. I discarded the two disasters with irregular entries, one in the early 1960s in Uganda and another in Luxembourg. I also replaced zeros for disaster impact estimates with a nominally low value (0.1) so that all variables could be analyzed in log form. I also replaced zero estimates of GDP per capita (due mostly to lapses in record-keeping, as in Afghanistan under the Taliban) with the lowest recorded value for GDP per capita in the sample.

The final step before running the bootstrap was to divide the sample with damage estimates into a training set and a set for cross validation. To do so, I randomly selected 25 percent of the disasters with damage estimates and set them aside to cross-validate my fitted regression. This left me with a total of six data sets. The number of disaster events in each set is available in table 2.1.

2.2 Bootstrapping additional estimates of economic damages

I bootstrapped economic damage estimates using the Bayesian statistical program JAGS and a varying-intercept model (equation 3.1) adapted from Gelman and Hill (2007). This model, where each disaster is subscripted i, estimates separate damage equations for each disaster type based on diffuse priors. The model is not hierarchical, insofar as there is no linkage of data across disaster types. I decided against modeling with informative priors or a hierarchical model, two potential advantages of using Bayesian techniques. Nevertheless, I preferred Bayesian methods because they do not impose an assumption of stationarity in the underlying model parameters and they facilitate simple bootstrapping.

$$
\begin{aligned}
\log \text{damage}_i &\sim \mathcal{N}(\hat{y}_i, \sigma_y^2) \\
\hat{y}_i &= a_{\text{disaster type},i} \\
&\quad + b_1 * \log \text{GDP per capita}_i \\
&\quad + b_2 * \log \text{affected}_i \\
&\quad + b_3 * \log \text{killed}_i \\
a_{\text{disaster type}} &\sim \mathcal{N}(\mu, \sigma_a^2) \\
\mu, b &\sim \mathcal{N}(0, 1000) \\
\sigma^2 &\sim \mathcal{U}(0, 100)
\end{aligned}
\tag{2.1}
$$

Table 2.2 presents parameter estimates for equation 3.1 fit to the main training set (i.e. excluding the outlier training set.) Trace and density plots of the regression parameters after $50,000$ iterations, with no thinning on the basic data set are shown in Appendix C: Miscellaneous's figures 17 through 21. They indicate good mixing of the simulation chains with the $\hat{R}$ parameter in 2.2 at 1.001 or below for all parameters.

The regression indicates that the most important factor associated with a disaster's damages is log GDP per capita in the country-year where it occurred. The mean estimate from the model indicates that a 1 percent increase in GDP per capita is associated with a 0.53 percent increase in economic damages. The second strongest factor in the model is log of people killed in the disaster, with a 1 percent increase in the number of people killed in a disaster associated with 0.42 percent more economic damage. Finally, a 1 percent increase in the number of people affected by the disaster was associated with an increase in economic damages of 0.2 percent. All three parameters have 95 percent probability intervals well above zero and all three parameters appear largely distinct from one another, with only a slight overlap of the 95 percent probability intervals for the log GDP per capita and log of people killed in the disaster. This means that they are above zero and their order of relative importance is stable, with high probability.

Interestingly, the regression shows significant overlap between all the 95 percent probability intervals of the regression intercepts, indicating that none of the disaster types distinguished themselves as being particularly devastating, independent of the country or people they impacted. While the various disaster types are not distinct from one another with high probability, the gap between the mean estimate of the least (Mass movement wet) and most (Drought) impactful disaster type is large enough to be of fundamental economic importance. Independent of specific impacts (people killed etc.), a drought is associated with 94.8 percent more economic damage than a mudslide (Mass movement wet) according to the mean parameter estimates from the model.

Table 2.2: Diagnostics for Bayesian regression of economic damages given population affected, population killed, and GDP per capita the disaster's country-year

	mean	sd	2.50%	25.00%	50.00%	75.00%	97.50%	$\hat{R}$	n.eff
a[1] Flood	-3.147	0.353	-3.837	-3.383	-3.150	-2.909	-2.444	1.0010	24000
a[2] Storm	-2.856	0.359	-3.559	-3.097	-2.858	-2.615	-2.147	1.0010	23000
a[3] Earthquake	-2.593	0.378	-3.332	-2.847	-2.594	-2.343	-1.844	1.0010	24000
a[4] Drought	-2.416	0.416	-3.220	-2.699	-2.415	-2.138	-1.599	1.0010	18000
a[5] Extreme temperature	-2.906	0.461	-3.809	-3.217	-2.909	-2.598	-1.999	1.0010	24000
a[6] Mass movement wet	-3.364	0.464	-4.298	-3.675	-3.356	-3.048	-2.465	1.0012	7600
a[7] Wildfire	-2.852	0.425	-3.684	-3.140	-2.854	-2.569	-2.017	1.0010	24000
a[8] Volcano	-3.287	0.512	-4.323	-3.623	-3.271	-2.938	-2.324	1.0010	24000
a[9] Epidemic	-3.177	0.693	-4.715	-3.560	-3.129	-2.728	-1.965	1.0010	24000
a[10] Insect infestation	-3.025	0.616	-4.302	-3.399	-3.007	-2.629	-1.846	1.0010	20000
a[11] Mass movement dry	-3.072	0.661	-4.488	-3.458	-3.037	-2.651	-1.851	1.0010	24000
b1 Log GDP per capita	0.533	0.030	0.473	0.512	0.533	0.553	0.592	1.0009	24000
b2 Log affected	0.200	0.019	0.162	0.187	0.200	0.213	0.238	1.0010	18000
b3 Log killed	0.422	0.028	0.368	0.404	0.422	0.441	0.478	1.0009	24000
mu.a	-2.972	0.409	-3.787	-3.243	-2.970	-2.698	-2.181	1.0010	24000
sigma.a	0.481	0.233	0.175	0.323	0.435	0.584	1.066	1.0009	24000
sigma.y	2.391	0.033	2.327	2.368	2.391	2.413	2.457	1.0011	10000

Figure 2.2 shows the in-sample prediction of the model based on equation 3.1. It includes sub-sample of high disaster with high affected to GDP/capita ratios that I estimated using its own regression. The straight black line in the figure is a benchmark for a one to one correspondence between the model's predicted damages for a disaster and the actual observed values in the EM-DAT database. The black line runs directly through the cluster, indicating that the model provides a reasonable in-sample fit. It reliably infers the order of magnitude of a disaster's damages using only the disaster type, GDP per capita, and the numbers of people affected and killed.

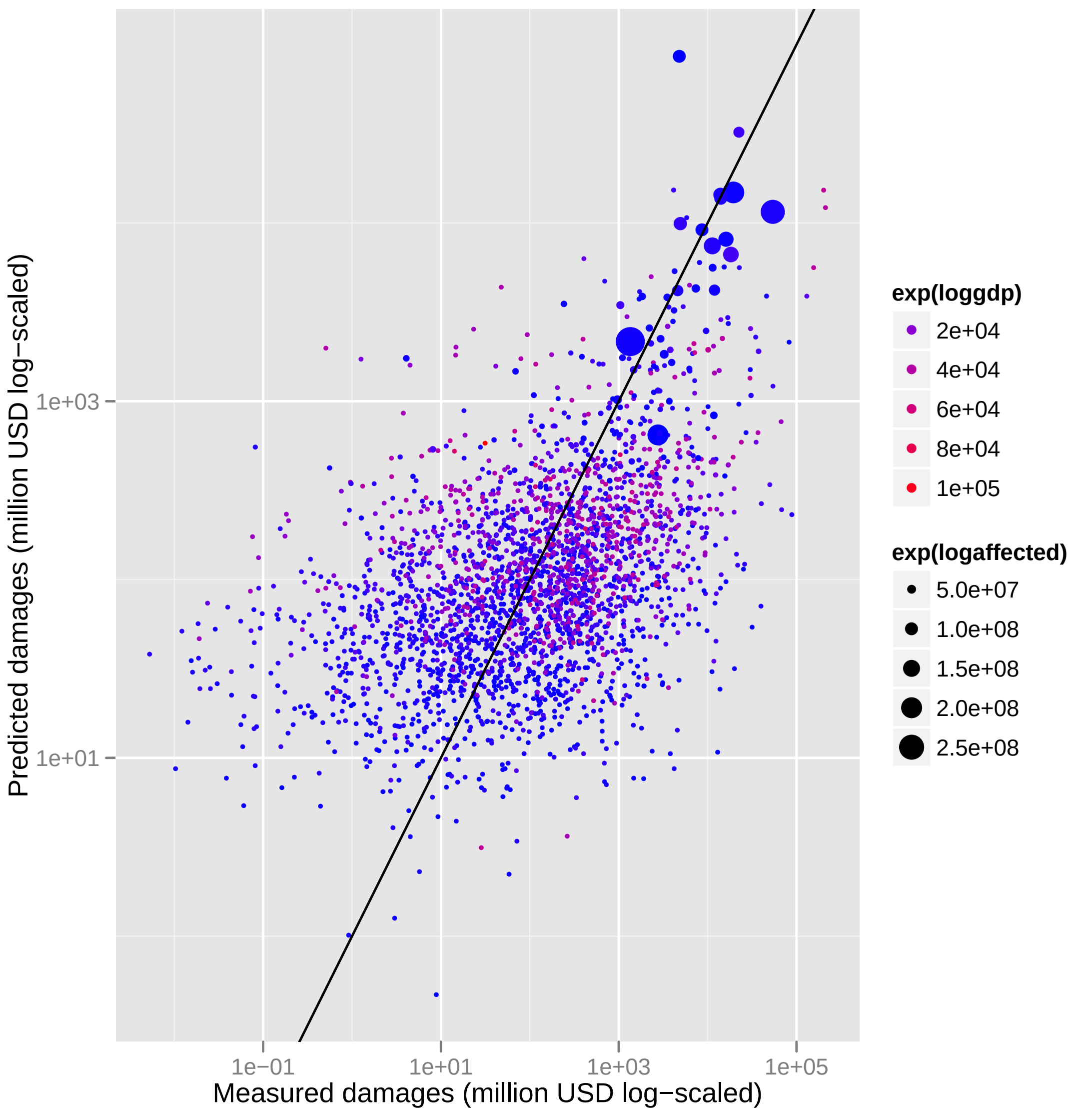


Figure 2.2: In-sample fit of estimated economic damages vs. actual economic damages from EM-DAT

When I used the model to model damages in the cross-validation set, it produced predictions that were similarly in line with observed damages. Figure 2.3 presents observed and predicted damages for the cross-validation set. As with the in-sample prediction in figure 2.2, the straight black line indicates perfect correspondence between modeled and observed damages. It runs directly through the main cluster of observations. That suggests that the fitted models offer reasonable inference on out-of-sample disasters.

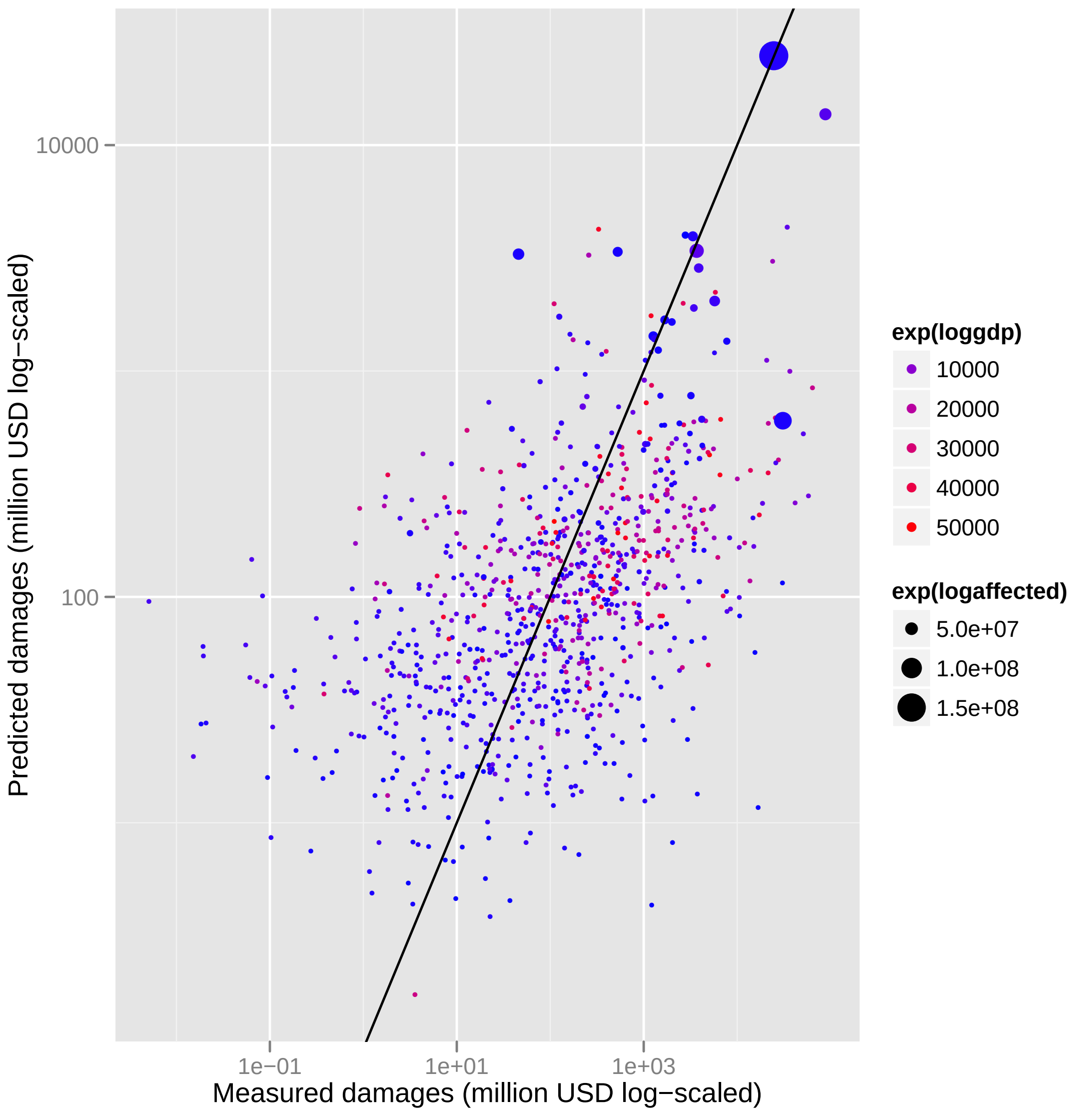


Figure 2.3: Cross-validation of estimated economic damages vs. actual economic damages from EM-DAT

Based on this cross-validation, I determined that the model was robust and used it to infer damages for the subset of the EM-DAT database without observed damages. After excluding disasters that I did not believe could be linked to regional climate anomalies (985 earthquakes and 191 volcanic eruptions) and discarding disasters without a reported start month, I was left with a sample of 9979 events between 1960 and 2010, disasters with economic damage estimates that I considered relevant to teleconnection indexes. Roughly two-thirds of those damage estimates came from the bootstrapping outlined in this chapter.

Chapter 3

El Niño-Southern Oscillation (ENSO)

This chapter presents my analysis of the El Niño-Southern Oscillation (ENSO) climate phenomenon and its economic impacts. This work provides the first line of evidence in support of traded markets in ENSO risk. The chapter includes:

- a description of the ENSO as a climate phenomenon;
- a brief discussion of what current climate science tells us about ENSO's impacts;
- an introduction to indexes of ENSO (see chapter 4 for additional information on ENSO-related SST dataset); and
- statistical analysis of the correspondence between the ENSO index and disaster damages (estimated in chapter 2) around the world.

3.1 Introduction to El Niño-Southern Oscillation

ENSO refers to a coupled oceanic/atmospheric cycle, its occasional break-down called El Niño, and supercharging called La Niña. In normal years, the ENSO cycle refers to currents and winds (each reinforcing the other) that bring water along the surface of the Pacific ocean from South America (from the eastern side of the Pacific) to Indonesian and the South Pacific (the western side of the Pacific). As that water travels along the ocean surface, it warms, thanks to the intense sunlight in the tropics. This results in water piling up on the Pacific's western side[1] actually making sea levels measurably higher in Indonesian than in Peru. As this mass of warm water accumulates, much of it sinks deeper into the ocean, where it naturally flows back east, across the Pacific, toward South America. By the time that the subsurface mass or water has reached the South American coast it is cold, allowing it to store more of the nutrients that serve as the basis of a vibrant aquatic ecosystem. So, as it springs up to replace the water moving west, it enriches the fisheries off Peru and Chile.

During an El Niño anomaly, this cycle weakens. (See figure 3.1 modified from Rosenzweig and Hillel (2008) below.) As less water reaches the western end of the Pacific, sea-surface temperatures rise. Over the course of the year, a plume of warmer-than-normal water creeps eastward across the Pacific. When that plume of warm water reaches Peru, it parks a moisture laden air mass off the coast. When that mass meets cold air coming east to west over the Andes mountains, Peru suffers catastrophic downpours and flooding.

By contrast, during a La Niña anomaly the normal cycle enhances. More water gets pushed from the South American coast, raising sea-surface temperatures in Australia and Indonesia above normal. That leaves Southeast Asia and Oceania with the

[1] Confusingly, the Western Pacific bumps up against South*east* Asia.

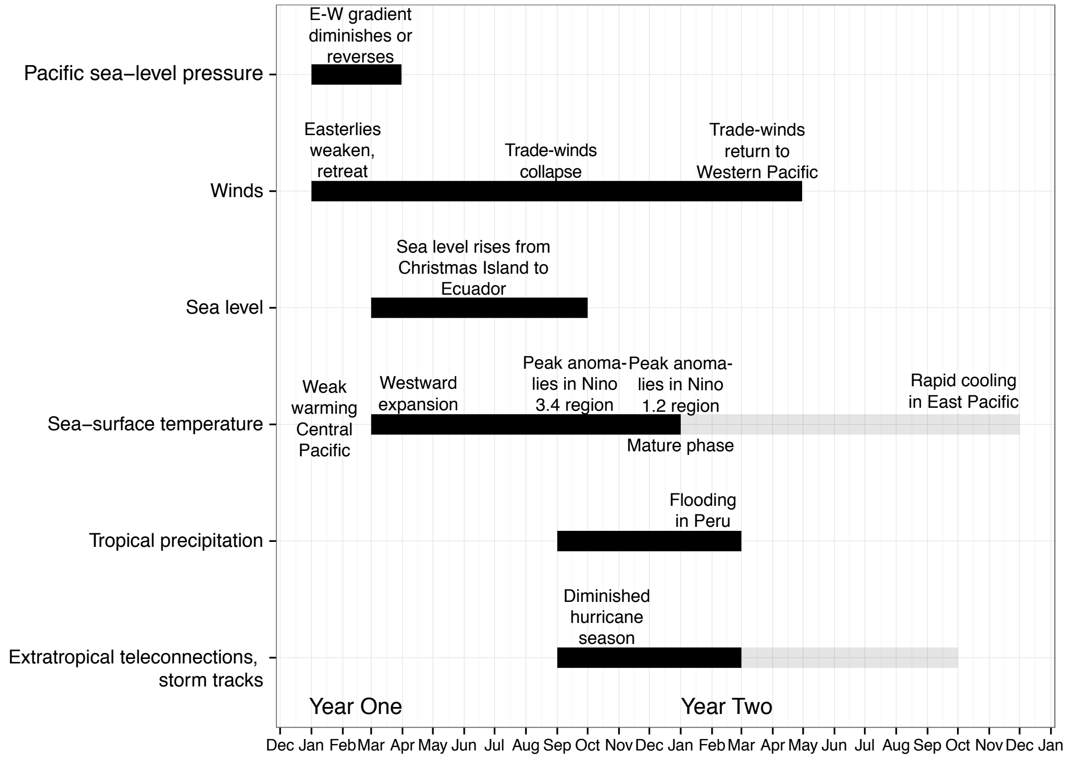


Figure 3.1: Calendar of average El Niño event, modified from Rosenzweig and Hillel (2008). Gray indicates impacts contingent on the strength of the event. Note that the calendar for any one ENSO events can vary greatly.

same problem as Peru during El Niño. A warm air mass sits in the region waiting for the opportunity to cause extreme rains and floods.

The ENSO cycle drives weather patterns well beyond Australia, Indonesia, and Peru. Figures 3.2 and 3.3 summarize global precipitation and temperature impacts for El Niño. La Niña shows opposing impacts, with a similar geographic footprint, but not necessarily of the same magnitude.[2]

Below are indicative publications covering regional or peril-specific ENSO impacts in greater depth:

Global impacts

- Worldwide precipitation patterns

  Ropelewski and Halpert (1987) and Ropelewski and Halpert (1989) are seminal papers looking at the footprints of ENSO anomalies between 1875 and 1983. The basis for figures 3.2 and 3.3, they identify regions (19 for El Niño

[2]Rosenzweig and Hillel (2008) provides an excellent non-technical overview of research related to the economic impacts ENSO around the globe.

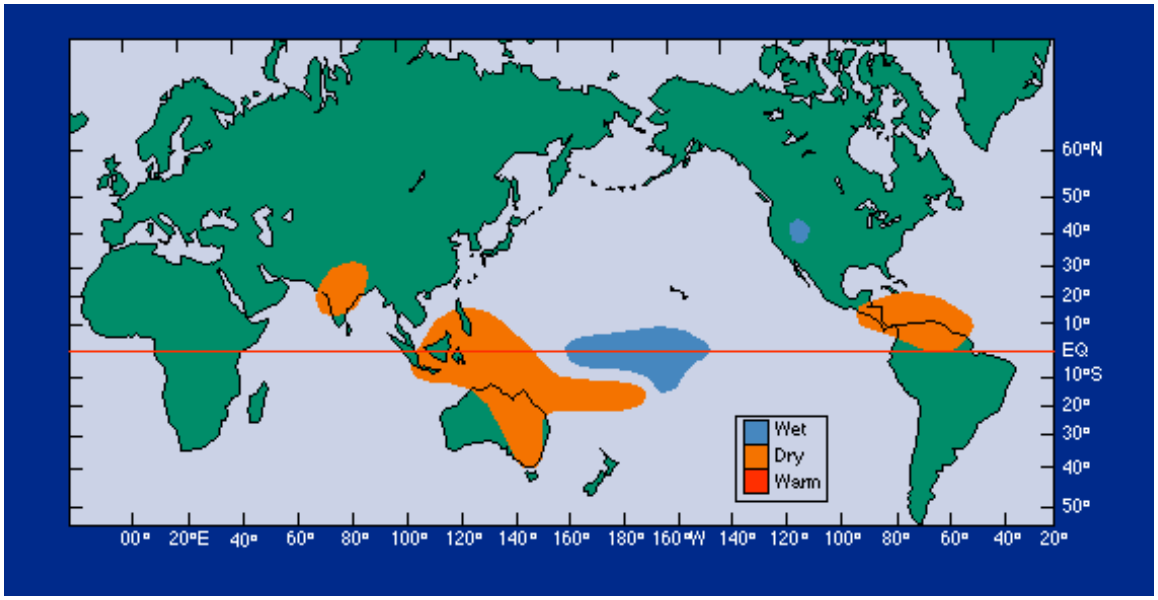


Figure 3.2: El Niño global impacts during the Northern Hemisphere summer

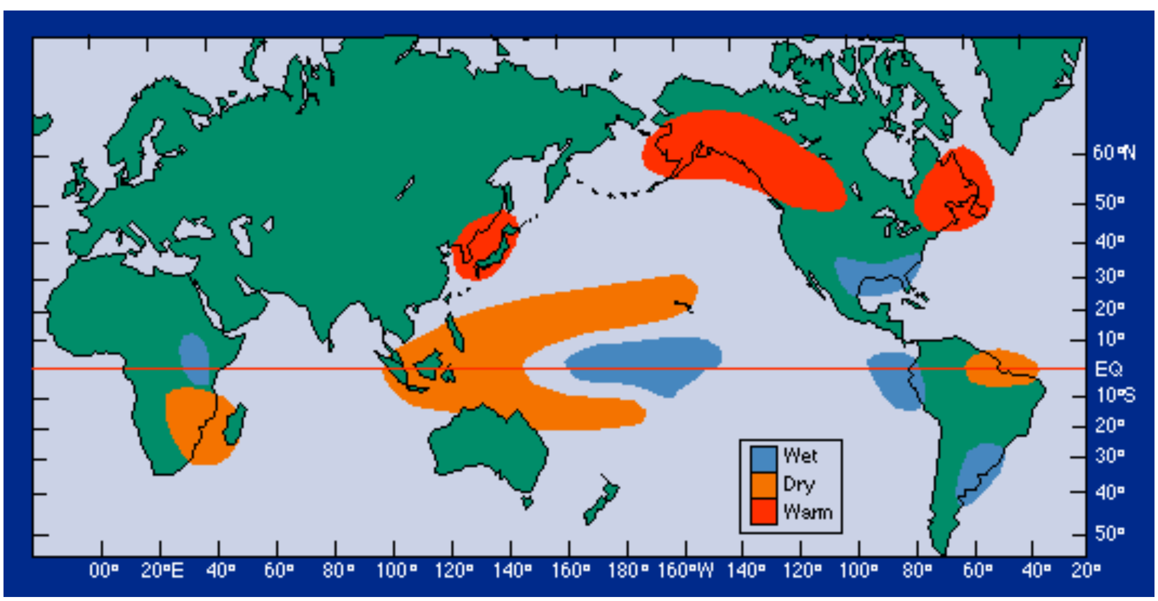


Figure 3.3: El Niño global impacts during the Northern Hemisphere winter

and 15 for La Niña) where precipitation has a statistically significant link to the ENSO cycle.

Mason and Goddard (2001) provides a more recent probabilistic estimates of ENSO's influence on precipitation across the globe.

Global studies provide an excellent starting point for understanding ENSO's importance to catastrophic weather. But they rely on global datasets with uneven coverage in the developing world. Judging by Mason and Goddard (2001), alone you might conclude that El Niño has a stronger influence on precipitation in the southwestern United States than in southern Peru and southern Ecuador. That is an artifact of the data that regional studies can address. Below are indicative citations that illustrate hedging opportunities that may be obscured in global ENSO research:

Regional impacts

- Flooding in the tropical Andean countries during El Niño

  Khalil et al. (2007) was prepared in association with GlobalAgRisk's Gates Foundation-supported work on El Niño insurance for northern Peru. It looks at the link between different ENSO indexes and extreme rainfalls in the Department of Piura, the local basis risk on those indexes, and the influence of climate change on regional flooding. It also addresses the trade-off between basis risk and advanced payments using earlier months' index values for insurance.

- La Niña/El Niño flooding/drought in Australia

  Chiew et al. (1998) provides an overview of the relationship between ENSO and rainfall, drought and streamflow in Australia. The analysis shows that ENSO is a statistically significant predictor of hydrological conditions across Australia. In particular, dry conditions in Australia tend to be associated with El Niño. The authors suggest that ENSO is, on its own, a useful forecasting tool for spring rainfall in eastern Australia and summer rainfall in north-east Australia. It is also helpful in predicting spring runoff in south-east Australia and summer runoff in the north-east and east coasts of Australia. However, autocorrelations diminish ENSO's value as a stand-alone predictor of Australian streamflows.

- Suppressed Atlantic hurricane activity during El Niño

  Klotzbach (2011) finds ENSO is the the primary interannual driver of variability in Caribbean hurricane activity, boosting hurricane activity in La Niña years and suppressing it in El Niño years. The article also examines interaction effects between ENSO and the Atlantic multidecadal oscillation.

- Flood and drought in the Southern Cone during El Niño and La Niña respectively

  Grimm, Barros, and Doyle (2000) analyzes precipitation and circulation across South America's Southern Cone. It finds significant links to the ENSO cycle, both across the region and in eight distinct subregions. The strongest subregional association links above-average rainfall in Southern Brazil to El Niño.

- Drought in Northeastern Brazil during El Niño

  Hastenrath (2006) looks at ENSO's influence on the short rainy season (covering just March and April) in the Nordeste region of Brazil. Like northern Peru, the Brazilian Nordeste has a particularly high incidence of poverty and a history of dramatic precipitation events (drought in Brazil) coincident with extreme El Niño. Hastenrath (2006) examines the climate drivers behind the region's recurrent Secas (droughts) with a focus on ENSO.

- La Niña/El Niño flooding/drought in Southeast Asia

  Murty, Scott, and Baird (2000) looks at the acute airborne pollution in Malaysia likely sparked by the 1997/1998 El Niño. That season brought Indonesia's worst drought in 50 years which in turn sparked a forest fire on the island of Borneo that engulfed over one million acres. This article summarizes the climatic roots of that disaster and looks at how they interacted with land management decisions to export the catastrophic consequences of an ENSO anomaly beyond its core region.

- Suppressed Indian monsoon activity during El Niño

  Kumar et al. (2006) suggests that over the last 132 year El Niño events have been a necessary, but not sufficient, prerequisite to shortfalls in the Indian monsoon. The article suggests that Central-Pacific (Modoki) El Niños have a stronger link to Indian drought than classical Eastern Pacific El Niños. The article explains these differing El Niño signatures using an atmospheric general circulation model.

- Drought in the West African Sahel during El Niño

  Janicot, Trzaska, and Poccard (2001) explores the unstable relationship between Sahel rainfall and ENSO in the northern summer. Looking at 20 year running correlations between Sahel rainfall index and ENSO SST between 1945 and 1993, the article suggests that the correlation between El Niño and drought has changed over time. While it was not signficant in the 1960s, it strengthened and has been significant since 1976. The article proposes interactions with multi-decadal oscillations as a cause of that change.

- Flooding in East Africa during El Niño

  Indeje et al. (2000) investigates above-average rainfall linked to El Niño through in the data of 136 weather stations across Kenya, Uganda and Tanzania between 1961 and 1990. Using both an empirical orthogonal function (EOF) and basic correlations, the article identifies eight subregions with distinct rainfall patterns. The article agrees with previous studies suggesting a modest tendency toward above-average rainfall in El Niño years followed by below-average rainfall the next year.

- Drought in Southern Africa during El Niño

  Camberlin, Janicot, and Poccard (2001) looks at the connection between ENSO and precipitation anomalies across Africa. The article confirms previous findings that El Niño is linked to drought in East Africa (shortfalls in the rainy season betweens July and September in Ethiopia and between October and December in the east equatorial countries) and in Southern Africa, especially during the second part of its rainy season. Southern African rains also show a link to teleconnections based in the Indian Ocean, which may account for droughts in South Africa not associated with the ENSO cycle.

3.2 Index construction

ENSO anomalies are multifaceted phenomena involving feedback loops from many climate systems. However, most major NMS define El Niño/La Niña just by looking at one simple index, the temperature of the sea-surface, relative to its seasonal average in specific regions across the Pacific. Generally, NMS prefer to average their SST measurements across a month or months, but they also issue more frequent measurements. Hence, in its most basic form, the index tracking ENSO anomalies is directly interpretable.[3]

The index-based insurance purchased by Caja Nuestra Gente in 2012[4] used as its sole payment trigger November and December measurements of the NOAA-defined region know as Niño 1.2, which lies directly off the Peruvian coast. (See figure 3.4 for a map of NOAA's Niño regions.) If the average of NOAA's November and December 2013 SST readings for the Niño 1.2 region is 24°C or above, then Caja Nuestra Gente will receive an insurance payment for the occurrence of a severe ENSO anomaly.

Niño 1.2 is the best predictor of catastrophic flooding in Peru and Ecuador, El Niño's flagship impact. However, NMS generally mark ENSO anomalies using the Niño 3.4 region[5] (roughly, from 5°N to 5°S and from 120° to 170°W), which stretches across the central Pacific Khalil et al. (2007) Barnston, Chelliah, and Goldenberg (1997). Both regions, Niño 1.2 and the Niño 3.4, have a very high correlation during extreme anomalies. But Niño 3.4 is generally considered a better proxy for the worldwide teleconnections associated with ENSO. In particular, it does a better job capturing ENSO anomalies with different geographic signatures. During the 1972/1973 El Niño, for example, most of the sea-surface temperature warming occurred in the central Pacific, closer to Niño 3.4. El Niño events focused on the Central Pacific are also called *Modoki* Niños and can have large global impacts Ashok et al. (2007).

[3] The indexes of of some other regional climate anomalies like the AO (discussed in chapter 11) require graduate-level mathematics to calculate and are not denominated in simple units like degrees.

[4] 2012 marks the second year in a row that the bank has purchased the coverage designed by GlobalAgRisk.

[5] Niño 3.4, straddles two separate regions, Niño 3 and Niño 4.

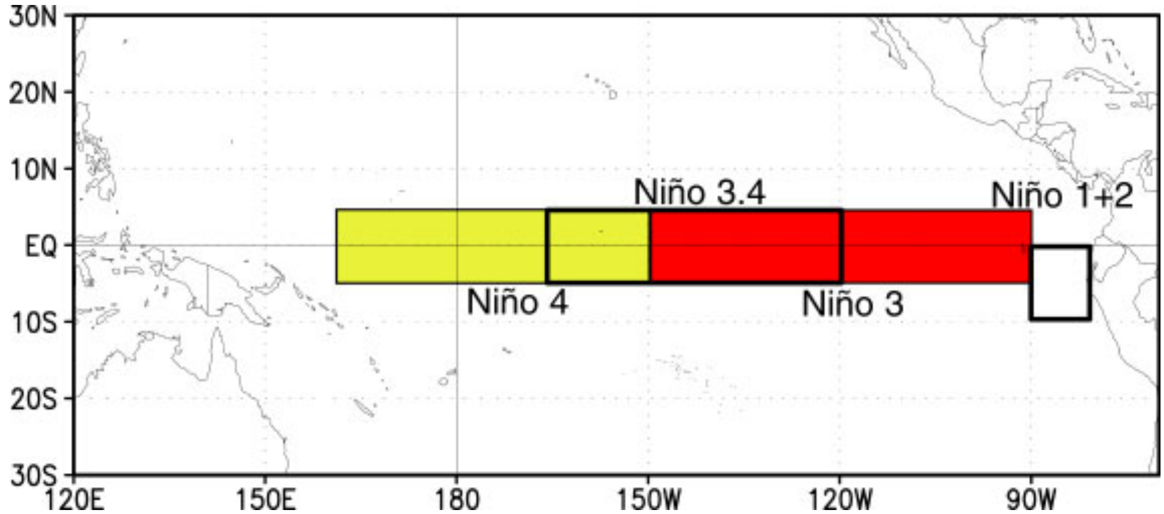


Figure 3.4: NOAA's Niño SST regions from `http://www.cpc.ncep.noaa.gov`

While month-by-month sea-surface temperatures alone provide a functional benchmark for extreme ENSO anomalies, NOAA's default index for ENSO anomalies, the Oceanic Niño Index (ONI), attempts to correct for two important statistical dynamics related to ENSO. First, the teleconnections associated with ENSO, correspond best to high sea-surface temperatures sustained across a few months. Consequently, ONI uses a 3-month mean SST anomaly (i.e. each month is reported as degrees above its average temperature) averaged over the Niño 3.4 region. Second, average sea-surface temperatures in the Niño 3.4 region have demonstrated a slight upward bias in recent decades. You can clearly see the bias in figure 3.5, where monthly averages over successive 30 year periods have been creeping upward. This raises the possibility that "El Niño and La Niña episodes that are [normalized to] a single fixed 30-year base period (e.g. 1971-2000) are increasingly incorporating longer-term trends that do not reflect inter-annual ENSO variability." Lindsey (2013) To correct for this, the ONI index takes each 3-month mean sea-surface temperature from the Niño 3.4 regions and divides it by a corresponding average for a rolling base period. For example, the March 1950 ONI value is equal to the average of Niño 3.4 temperatures for January, February, and March, divided by the January, February, and March average between 1936 and 1965. For recent data, NOAA uses the 1981-2010 base period. This means that recent values are subject to revision. NOAA currently changes the base period for readings every decade, but as of 2016 will begin updating the base period every 5 years.

The ONI index is more difficult to interpret than simple monthly sea-surface averages. I suspect that this makes it less suitable as the basis of an exchange traded risk management contracts. However, I believe the smoothed index provides a solid foundation for this initial statistical analysis.

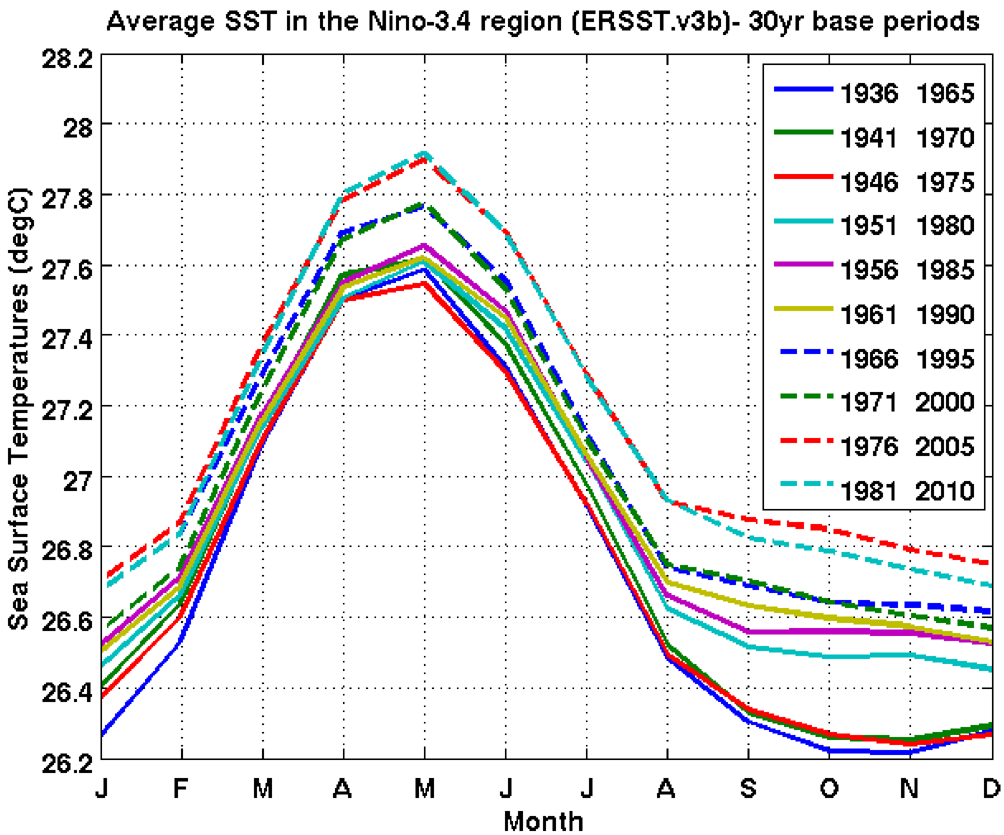


Figure 3.5: Long-term warming trend in Niño 3.4 region from NOAA `http://www.cpc.ncep.noaa.gov/products/analysismonitoring/ensostuff/ONIchange.shtml`

3.3 Statistical analysis of EM-DAT disasters

Researchers have used the EM-DAT database to estimate ENSO's global impacts. But there are clear opportunities to enhance that literature. Bouma et al. (1997), for example, identified a strong link between the ENSO cycle and the number of people affected by disasters globally. But curiously, part of the uptick is linked to increased volcanic activity in years following El Niño events.

Goddard and Dilley (2005), by contrast, found that the overall frequency of hydrological disasters in the EM-DAT database was not significantly higher during El Niño or La Niña events than during ENSO neutral periods. That analysis also found weak evidence of trends in aggregate precipitation over land areas associated with ENSO extremes.

Goddard and Dilley (2005)'s finding are not surprising. First, ENSO represents shifts in burden of disaster across the globe and changes in the magnitude of disaster impacts. Indeed without some zero-sum-like shift in disaster burden, there would be little advantage to managing ENSO risk on an exchange, with relative winners from any ENSO state trading risk with relative losers in that state. Second, as discussed in chapter 2, the EM-DAT database has some evident short-comings as a proxy for ENSO impacts, which I have worked to correct. Even after my augmentation of missing data from the EM-DAT database, flooding in northern Peru between January and April, the largest and most dramatic impact of El Niño, hardly appears in the database. For that reason, I believe that accurate disaster impact statistics require Bayesian analysis which allows me to reference outside assessments of regional ENSO impacts as I extrapolate from the disaster statistics I compiled in the last chapter.

Figure 3.6, shows disaster burden data aggregated across the world next to the historic time series of the ONI index, with extreme El Niño events marked in red and La Niña events marked in blue. As Goddard and Dilley (2005) noted, it is difficult to identify clear tends in any of the disaster types.

To identify groups of ENSO hedgers, my analysis segregates country-disasters into groups that likely have similar hedging interest. In my ENSO analysis I use four large groups:

- Flood and epidemics on South America's Pacific Coast - Countries on the Pacific coast of South America tend to face flood and epidemic risk associated with El Niño. Some countries, such as Peru have experienced both flood and drought in extreme La Niña years, but the physical and statistical link with regional drought is less strong than for El Niño.

- Drought across the Southern Atlantic and Indian Ocean Basin - Historically many countries have experienced drought in ENSO years. The strongest links are with Pacific Asia and Oceania and Atlantic South America. There are also important potential links between ENSO and droughts in Southeast Asia, and Eastern/Southern Africa. Given the link between drought and wildfire, wildfire incidence is also included in this grouping.

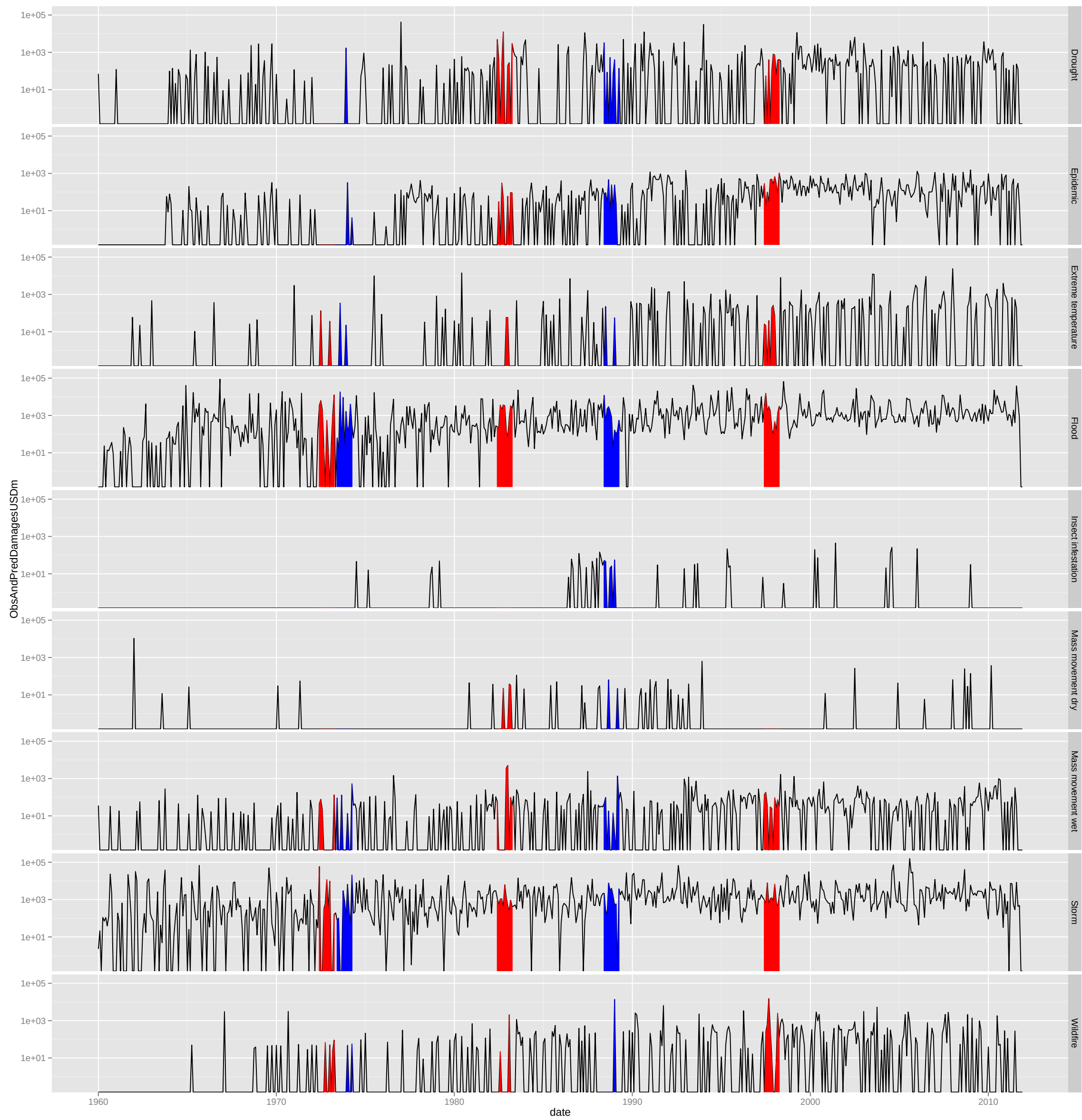
- Storms in North America and the Caribbean - Perhaps the most economically important offset for an ENSO market stems from the an inverse correlation between ENSO and storm activity in the Western Atlantic.

- Flooding in Pacific Asia and Oceania - This impact is generally associated with La Niña.

Undoubtedly, there are other groups with important exposure to the ENSO index and I could achieve a more accurate estimate of ENSO damage by further distinguishing subgroups. However, I believe that this grouping should be large enough to avoid spurious correlations in the data but small enough that they will not mask regional exposures to specific disaster-types.

3.4 South America's Pacific Coast - Flooding, landslides and epidemics from El Niño

The economic impacts of El Niño are well known in Peru and Ecuador. Despite the clear link between El Niño and disaster in the region, there are relatively few extreme El Niño events in recent historical record (1972/73, 1982/83, and 1997/98) and



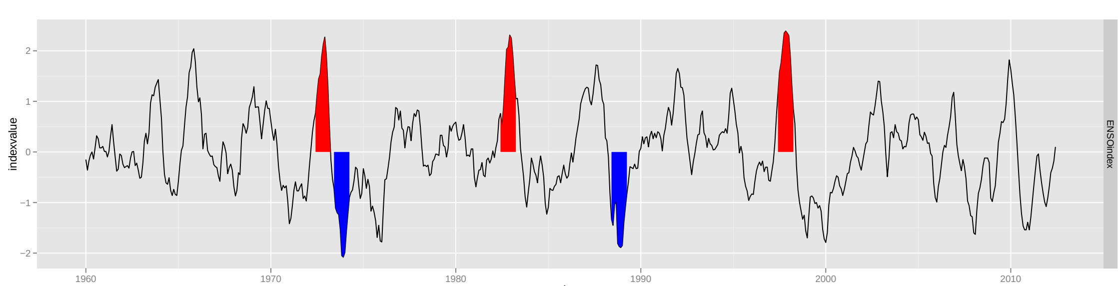


Figure 3.6: Worldwide disaster damage estimates by disaster type compared to ENSO (ONI) index

the region covers relatively few countries so statistical inference about the economic burden of El Niño in the region must come from relatively few disaster events.

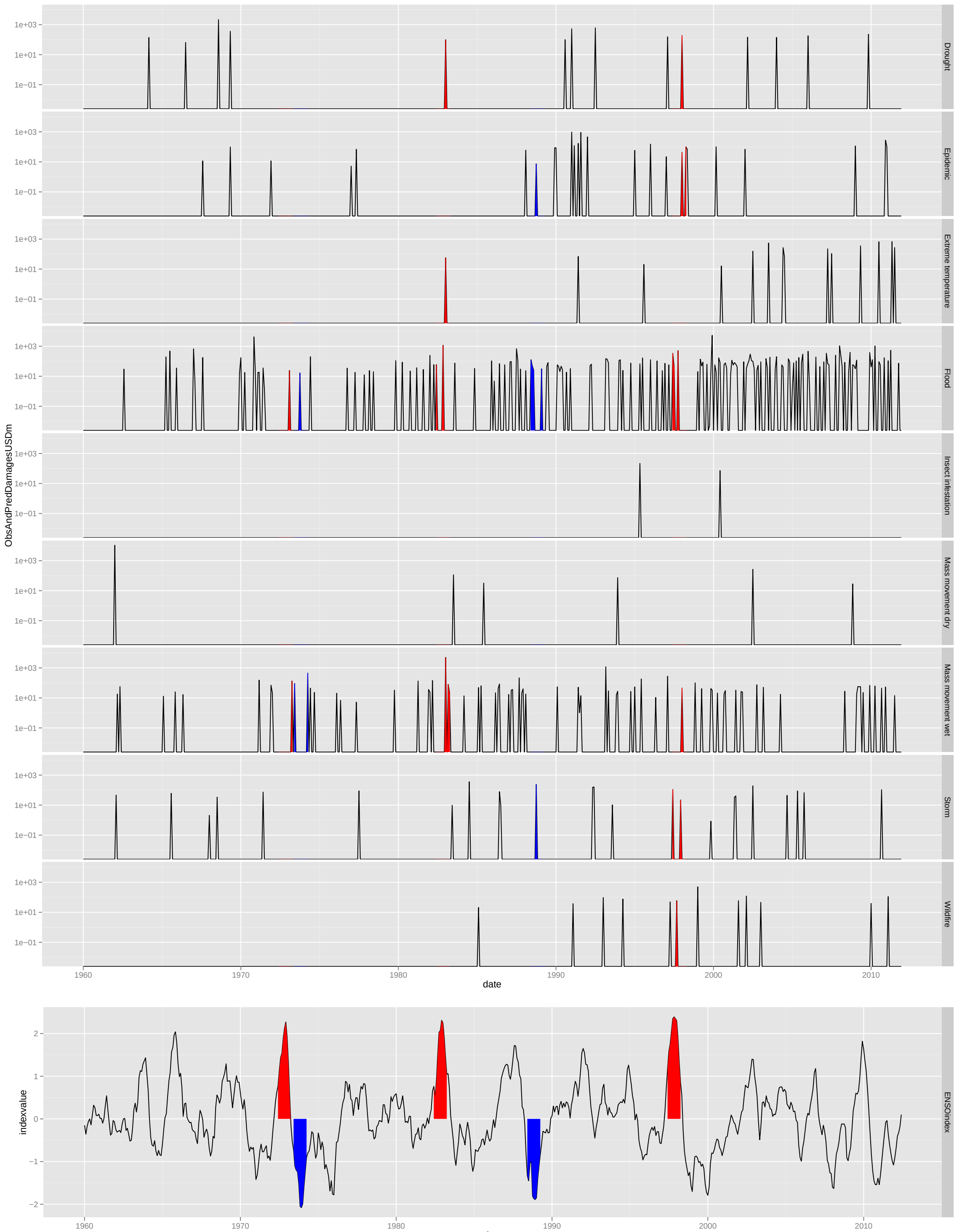


Figure 3.7: Disaster damage estimates by disaster type for countries along South America's Pacific coast compared to ENSO (ONI) index

In the typical extreme El Niño, sea surface temperatures off the coast of Peru hit anomaly levels in the last months of a given year and flooding begins in the first months of the following year. Based on that pattern, I aggregated damage due to flood, landslide, and epidemic in the first six months of each year between 1961 and 2010 and divided by the median annual damage over the period of study (roughly 259 m in 2010-USD). This sample included 192 separate disaster events.

To measure the influence of ENSO on, for example damages from January through June 2010, I averaged the ONI index[6] from October 2009 through January 2010. Using this technique, it is easy to distinguish the three extreme El Niño events in the recent series.

Using these time series (for the index and damages as a percent of the seasonal median), I performed the Augmented Dickey-Fuller Test and the Phillips-Perron Unit Root Test. Both tests favored the alternative hypothesis of stationarity with greater than 95 percent confidence. Neither, the index nor the damage time series showed significant autocorrelation using a standard autocorrelation function, indicating that there is only weak interaction between the values of one season and the next. As we have discussed earlier, many of the most prominent ENSO measurement indexes have show some upward bias in recent decades. However, the ONI index corrects for that bias.

I segregated the dataset to run separate regressions on:

1. El Niño seasons - those with an ONI average for October through January above 1[7]; and

2. Normal or La Niña seasons - those with a seasonal index below 1.

I chose to run separate regressions because I believe that the underlying process producing flooding and related disasters is distinct during moderate to strong El Niño conditions. This modeling decision likely reduces the power of inference, but allows for opposing slopes during each phase. I separate Bayesian regressions on each subset as indicated in equation 3.1.

I selected a diffuse prior for both the slope and the intercept for normal and La Niña years. The intercept's diffuse prior was centered on 1 and the slope's on 0, simply to account for the fact that the regression was stated in terms of median damages so most years in the sample will have a value of one and show no trend related to ENSO.

I selected an informative prior for El Niño based on damages estimates from Ecuador and Peru from the 1982/83 El Niño compiled in Rosenzweig and Hillel (2008) using data from Glantz, Katz, and Nicholls (1991), as well as Peruvian and UN reports. Those estimates placed the damages of that disaster at roughly USD 10.5 b. (This estimate is presumably in 1982/83 USD, so it would be larger if adjusted to

[6]Note that this index is based on a running average of monthly Niño 3.4 data.

[7]The ONI index is normalized such that a value of 1 indicates one degree deviation above the average value for the corresponding historical window (see index construction section for more details). The standard deviation of the dataset is 0.82, so a value of 1 is slightly greater than a one standard deviation anomaly.

present dollars.) That disaster corresponded to an ONI index value slightly above 2. I also assume that an ONI index of 1 (the point that distinguishes between normal and El Niño conditions) results in median damages. This gives me two points on which I can base my prior beliefs about the slope and intercept of the line describing El Niño damages. The move from an ONI of 1 to an ONI index of 2.165 resulted in approximately 4045 percent greater damage than the median year. That is equivalent to a slope parameter of 33.93.

I set a prior of $b_{\text{El Niño}} \sim \mathcal{N}(33.93, 5.5^2)$. Based on Gelman and Hill (2007) this is equivalent to providing one direct observation of the slope parameter with a weight that is slightly less than one single data point (because the standard deviation of observed damages is 5.37 less than the standard deviation of the prior.) In other words, this prior is slightly less influential to the final estimation than any single data point in the regression.

Implicit in my belief about the slope of the line, is a similar prior about the intercept parameter in the regression. If the effect of El Niño is negligible, then the intercept of the El Niño regression is 1, indicating losses that are 100 percent of the median. If the effect of a one point rise in my ONI index is to raise disaster damages to a level to approximately 35 times the median (the prior I assigned above), then then the intercept will be -33 (i.e. the line has a slope of 34 and runs through point $(1, 1)$). This range (an intercept between 1 and -33) is summarized in the prior $a_{\text{El Niño}} \sim \mathcal{N}(-16.0, 17^2)$. This is a relatively diffuse prior, and has a weight of considerably less than one data point.

$$
\begin{aligned}
\log \text{Jan-Jun damage as percent of median}_{\text{year t}} &\sim \mathcal{N}(\hat{y}_i, \sigma_y^2) \\
\hat{y}_i &= a_{\text{Niño phase}} \\
&\quad + b_{\text{Niño phase}} * \\
&\quad \text{mean Oct-Jan ONI index}_{\text{year t-1 through t}} \\
a_{\text{La Niña to normal}} &\sim \mathcal{N}(1, 1000) \\
a_{\text{El Niño}} &\sim \mathcal{N}(-16.0, 17^2) \\
b_{\text{La Niña to normal}} &\sim \mathcal{N}(0, 1000) \\
b_{\text{El Niño}} &\sim \mathcal{N}(33.93, 5.5^2) \\
\sigma_y^2 &\sim \mathcal{U}(0, 100)
\end{aligned}
\tag{3.1}
$$

The output from those regressions in table 3.1, indicates that with 95 percent probability, the slope on the El Niño regression is positive indicating that more extreme ONI index values are indeed associated with increased disaster damages. The mean slope for La Niña and normal seasons is close to 0, and 0 is with the 95 percent probability interval. That indicates a weak or non-existent relationship between disaster damages and ONI index values outside the El Niño range.

The slopes of the two regressions show no overlap in their 95 percent probability intervals. The regression indicates that an average ONI index reading of 2 for the months of October through January (historically strong El Niño conditions, which happened three times since 1970) was associated on average with a 1326 percent increase in economic damages due to flooding, mudslides, and epidemics - equivalent to roughly USD 3.4 b in absolute damages higher than during normal or La Niña conditions. (See figure 3.8 for more details.) Using the limits of the 95 percent probability intervals for the slope and intercept parameters, which imply the strongest and weakest link to ONI respectively, the regression suggests that the credible range for this figure is between USD 2.2 and 4.7 b.

Assuming that the probability of an extreme El Niño is roughly $\frac{3}{40}$ (with three large El Niño events since 1970), then the mean damages estimate suggests that the region will, at any given time, be interested in roughly USD 250 m of risk coverage against the ONI index.

Table 3.1: Diagnostics for Bayesian regression of economic damages along South America's Pacific coast from January to June on ONI October to January average

El Niño	Observed seasons	12							
	mean	sd	2.50%	25.00%	50.00%	75.00%	97.50%	$\hat{R}$	n.eff
a	-25.292	8.098	-42.289	-30.567	-24.921	-19.542	-10.655	1.0009	11000
b	19.278	5.371	9.637	15.445	19.046	22.855	30.392	1.0009	11000
sigma.y	9.910	3.464	5.059	7.442	9.282	11.665	18.451	1.0010	11000
La Nina to Normal	Observed seasons	41							
	mean	sd	2.50%	25.00%	50.00%	75.00%	97.50%	$\hat{R}$	n.eff
a	1.274	0.276	0.735	1.091	1.273	1.457	1.817	1.0013	4200
b	-0.194	0.322	-0.822	-0.406	-0.195	0.018	0.450	1.0009	11000
sigma.y	1.555	0.183	1.247	1.427	1.538	1.667	1.953	1.0010	11000

The difference in slopes is clear in figure 3.8 which shows a scatter plot of damage data alongside the mean regression line and the 95 percent probability interval for that regression.

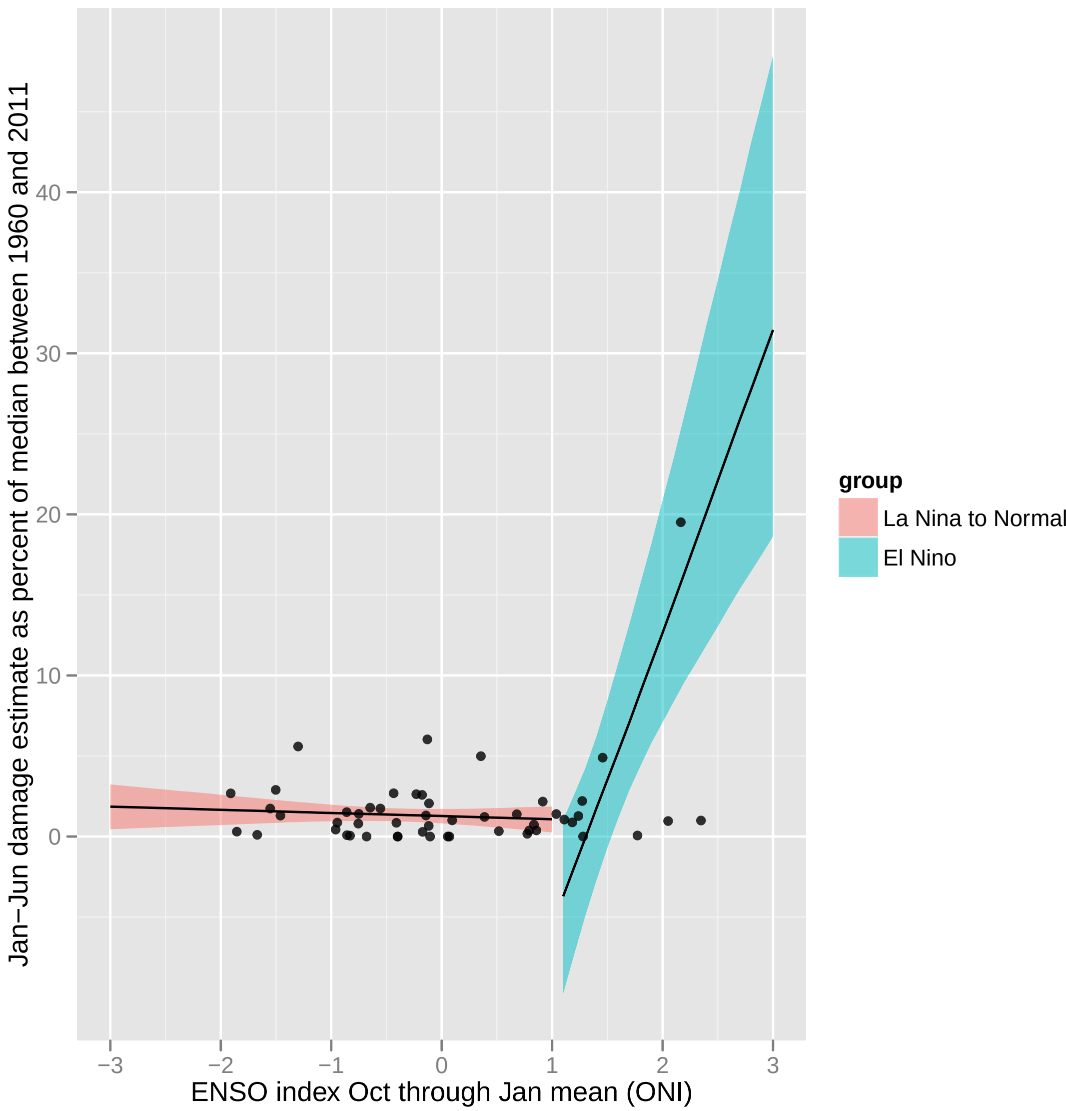


Figure 3.8: Bayesian regression of flood, landslide, and epidemic damages estimates from South America's Pacific coast, 1960-2011 predicted by ONI index

3.5 East Pacific Asia and Oceania - Flooding from La Niña

Stable, liquid markets in teleconnection index risk will require balanced populations of hedger with opposing risks. Assume that flooding in South America creates a group of hedgers that want to receive payment in El Niño years. What region is the natural counter-party for this hedge? There are two ways to identify likely counter-parties:

1. We could look for regions which could be considered winners from an El Niño. For example a region that is often in water deficit and receives above-average rainfall without suffering floods during El Niño. However, these gains are likely to be modest relative to the sudden and catastrophic losses caused by extreme El Niño. To balance the market, you would need participation from many of these counter-parties.

2. Alternatively, we could look for regions and industries that face opposing losses across time. These counter-parties are perhaps less desirable than El Niño winners. Setting up trades between La Niña/normal phase losers and El Niño losers requires long-term commitments from both parties. In interest rate markets hedgers swap fixed and adjustable rates on loans based on indexed contingencies. Similarly, El Niño hedgers could receive a lower interest rate on an outstanding loan (in the case of El Niño) and visa versa for La Niña hedgers. That type of hedge, while normally accomplished through OTC swaps markets today, could be mediated by futures and options on futures.

La Niña related flooding in Pacific Asia and Oceania could be the major driver of hedging activity in that second category. In this section, I analyze the EM-DAT database for trends related to La Niña.

Using the average ONI index between October and January, the largest La Niña events in recent history occurred in 1973/74, right on the heels of the Mododki El Niño of 1972/73, and in 1988/89[8]. See figure 3.9 for details.

ENSO events generally begin in the Central Pacific with a slowdown of the atmospheric/oceanic cycle that brings water upwelling off the South American coast toward Indonesia. As that cycle slows, often beginning as early as January (i.e. January 1997 for the 1997/98 El Niño), by April of that year those changes are visible in the Eastern and Central Pacific sea surface temperatures. Roughly by September, still in advance of the impacts felt on South America's Pacific coast (roughly in the first six months of the following year, 1998 for the 1997/98 El Niño), persistent sea surface temperate anomalies result in changes in patterns of precipitation in Pacific Asia and Oceania. (See figure 3.1 for more detail on the calendar of events.) For that reason, I analyze aggregate flood damage in the region from September of year t though August of year $t+1$ for its connection to the average ONI index between October of year t and January of year $t+1$ (the same index used in the South America section). This division means that in 1972/73, when El Niño conditions quickly changed to La Niña conditions in 1973/74, the flooding that occurred in September of 1973 in Pacific Asia and Oceania is matched with the 1973/74 ONI readings.

Rather than analyze raw disaster data, I again set the seasonal disaster impact as a percentage of the median through the period of study. The median estimated flood damages in Pacific Asia and Oceania between 1960 and 2010 was USD 3.07 b between September of year t and August of year $t+1$. Those damages covered 523 disasters in the EM-DAT database.

[8]By some index measures the 2010 and 2011 La Niñas were also among the strongest on record.

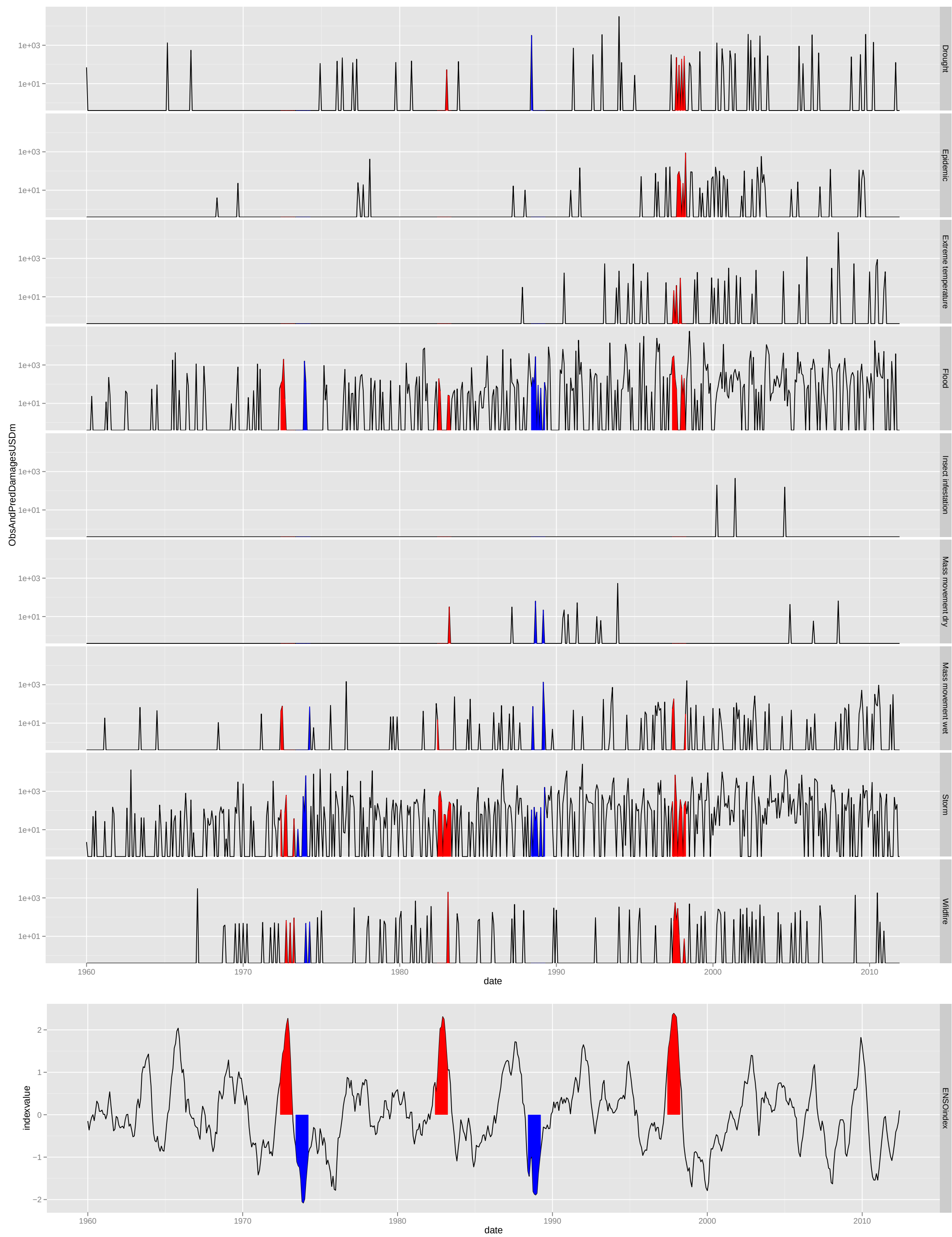


Figure 3.9: Disaster damage estimates by disaster type for countries in Pacific Asia and Oceania compared to ENSO (ONI) index

I performed the Augmented Dickey-Fuller Test and the Phillips-Perron Unit Root Test on the damage data. While the Phillips-Perron test favored the alternative hypothesis of stationarity with greater than 95 percent confidence, the Augmented Dickey-Fuller Test failed to reject the null hypothesis of non-stationarity. This indicates that there may be long term trends in flood damage in the region which could produce spurious correlations on OLS regressions. Stationarity is not strictly required for Bayesian analysis, because the underlying parameters of the regression are considered stochastic.

The damage time series did not, however, show significant autocorrelation using a standard autocorrelation function, indicating that there is only weak interaction between the values of one season and the next.

I selected an informative prior for La Niña damages by referencing my inference for the damages of El Niño on South America's coast. I believe that the influence of ENSO on flooding across this large region (Pacific Asia and Oceania) is more subtle than El Niño's effects on the Pacific Coast of South America. In the latter case, my analysis indicated that on average, a move from an ONI value of 1 to 2 provoked a twenty-fold increase in flood damages across the region relative to normal or La Niña conditions. Hence, I assume extreme La Niña (an ONI value of -2) will result in flooding in Pacific Asia and Oceania somewhere between the median for region and five times above the median.

When I combine this belief with the belief that normal conditions will result in median losses across the region, I can also make inferences about the intercept parameter in my regression. If the effect of La Niña is negligible, then the intercept of the La Niña regression is 1, indicating losses that are 100% of the median. If the effect of La Niña is equal to the effect of extreme El Niño in South America, then the intercept will be -4. This range (an intercept between 1 and -4 is summarized in the prior $a_{\text{La Niña}} \sim \mathcal{N}(-1.5, 2.5^2)$.

Given the tendency of some Pacific Islands to suffer from catastrophic flooding during El Niño, despite the regions' tendency toward drought, I broke the regression into three parts, rather than two UCAR (1994). This resulted in the regression equation listed in equation 3.2.

$$
\begin{aligned}
\log \text{Jan-Jun damage as percent of median}_{\text{year t}} &\sim \mathcal{N}(\hat{y}_i, \sigma_y^2) \\
\hat{y}_i &= a_{\text{Niño phase}} \\
&\quad + b_{\text{Niño phase}} * \\
&\quad \text{mean Oct-Jan ONI index}_{\text{year t-1 through t}} \\
a_{\text{La Niña}} &\sim \mathcal{N}(-1.5, 2.5^2) \\
a_{\text{normal}} &\sim \mathcal{N}(1, 1000) \\
a_{\text{El Niño}} &\sim \mathcal{N}(-1.5, 2.5^2) \\
b_{\text{La Niña}} &\sim \mathcal{N}(2.5, 2.5^2) \\
b_{\text{normal}} &\sim \mathcal{N}(0, 1000) \\
b_{\text{El Niño}} &\sim \mathcal{N}(-2.5, 2.5^2) \\
\sigma_y^2 &\sim \mathcal{U}(0, 100)
\end{aligned} \tag{3.2}
$$

The output from those regressions in table 3.2, indicate that:

- With 90 percent probability, the slope on the La Niña regression is negative. Hence, more extreme ONI index value are associated with increased flood damage in the region;
- With 95 percent probability, the slope on the El Niño regression is positive. So, extreme positive ONI index values are also associated with increased flood damage in the region;
- A slope of 0 for normal conditions is within the 95 percent confidence interval, but that interval is biased toward negative values;
- The 50 percent probability intervals of each the regressions' slopes are distinct, but there is some overlap between the 95 percent probability interval of all three slope parameters.

This indicates that while extreme values of the ONI index likely influence flood damage in the region, the connection would be clearer if I included information from climate research through Bayesian priors (as I do below for Atlantic storm damage) and changed the scale of analysis to the sub-regional level.

Based on the regression, the expected impact of a La Niña event of the same magnitude as that of 1988, an ONI index of -1.85 which was reached twice since 1970, was an 261 percent increase in regional flood damages relative to the median of slightly more than USD 8 b in absolute damages. (See figure 3.10 for more details.) While the impact of La Niña on flooding across the region is less pronounced than that of El Niño in South America, the expected damages are large in aggregate. In fact they are large enough to fully offset the hedging interest generated by El Niño along South America's Pacific coast, even after accounting for the fact that there have been only two major La Niñas since 1970 versus three major El Niños over the same period (i.e. adjusting for the probability of the extreme event in question by $\frac{2}{40}$ rather than $\frac{3}{40}$.)

My analysis indicates that futures and options on futures for ENSO index risk would enjoy large balanced hedging interest. However, market professionals will need to find clever ways to link natural counter-parties in the market across time such that Asian hedgers are willing to insure the losses of South American hedgers during El Niño years and visa versa for La Niña years.

Table 3.2: Diagnostics for Bayesian regression of economic damages in Pacific Asia and Oceania from September to August on ONI October to January average

La Niña	Observed seasons	9							
	mean	sd	2.50%	25.00%	50.00%	75.00%	97.50%	$\hat{R}$	n.eff
a	-1.045	1.756	-4.511	-2.213	-1.032	0.142	2.373	1.0010	11000
b	-1.979	1.208	-4.376	-2.778	-1.973	-1.174	0.393	1.0010	11000
sigma.y	2.205	0.713	1.286	1.721	2.060	2.517	3.913	1.0012	5800
Normal	Observed seasons	33							
	mean	sd	2.50%	25.00%	50.00%	75.00%	97.50%	$\hat{R}$	n.eff
a	2.012	0.559	0.927	1.642	2.002	2.379	3.128	1.0011	10000
b	-0.534	0.922	-2.352	-1.143	-0.529	0.063	1.286	1.0010	11000
sigma.y	3.097	0.420	2.397	2.802	3.051	3.343	4.031	1.0009	11000
El Niño	Observed seasons	12							
	mean	sd	2.50%	25.00%	50.00%	75.00%	97.50%	$\hat{R}$	n.eff
a	-0.714	2.086	-4.826	-2.118	-0.708	0.694	3.347	1.0010	11000
b	3.354	1.546	0.298	2.316	3.347	4.389	6.427	1.0012	5600
sigma.y	7.334	1.792	4.764	6.077	7.032	8.260	11.760	1.0012	6000

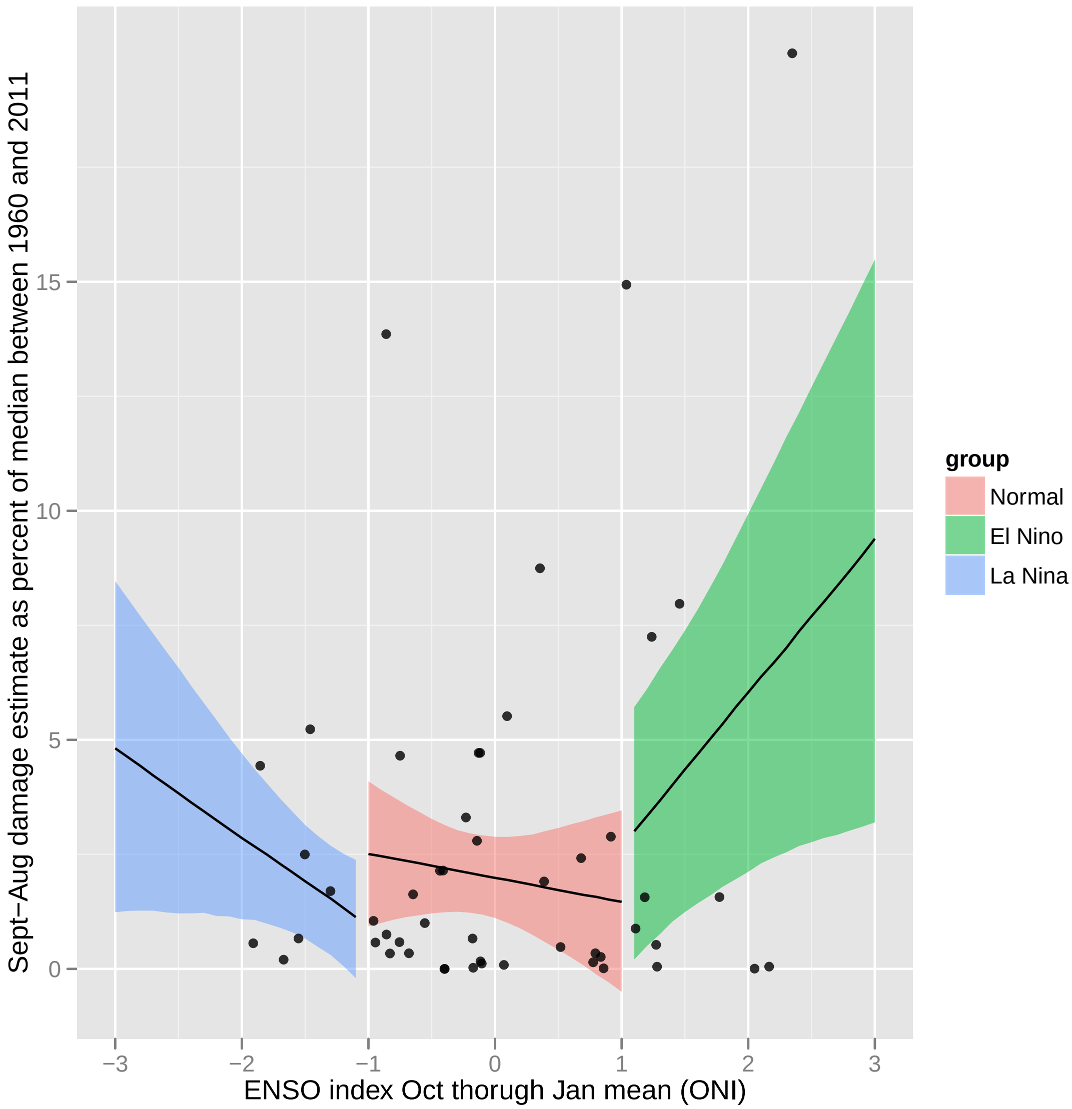


Figure 3.10: Bayesian regression analysis of flood damage in the East Asian Pacific and Oceania predicted by ENSO index

3.6 North America and Caribbean - Storms from El Niño

So far, I have discussed catastrophes that are direct results of ENSO anomalies. What distinguishes ENSO as a teleconnection index is its ability to reshape weather patterns across the globe, affecting regions and weather phenomenon with no obvious immediate connection to the ENSO event itself. This presents an opportunity. The hedging activity generated by otherwise disparate weather events could, in part, be driven to one central ENSO market, providing the liquidity, competition, and collective information that will drive ENSO protection prices steadily downward.

ENSO's link to Atlantic hurricanes is likely the most important of the true teleconnections (as opposed to the more direct linkages between ENSO and precipitation in the equatorial Pacific) that would drive liquidity on an ENSO market. Hedging interest related to hurricane damage might naturally come from the global reinsurance industry, the large insurers of insurers that specialize in spatially correlated risks. (See chapter 8 for more details on hedging interest from reinsurers.)

US hurricanes represent the largest single non-life risk in the portfolios of large reinsurers, hence any cost-effective hedging instrument that could help them share Atlantic hurricane risk, or bring non-hurricane risk into their portfolios to offset that hurricane risk, should be very valuable to reinsurers IAIS (2011). Figure 3.11 shows my own measure of CAT bond issuance by peril type between 1996 and 2011 (2012 data runs through March). CAT bonds are often considered a substitute for reinsurance. They also reflect the risk that reinsurers want to transfer out of their portfolios. The thick pink line in figure 3.11 is my estimate of cat bond issuance specific to US hurricane risk. As you can see, Atlantic hurricane risk has dominated catastrophe bond issuance virtually every year since the market's inception in 1996. (Figure 7.6 provides another estimate from a reinsurance brokerage with more aggregation of issuance.)

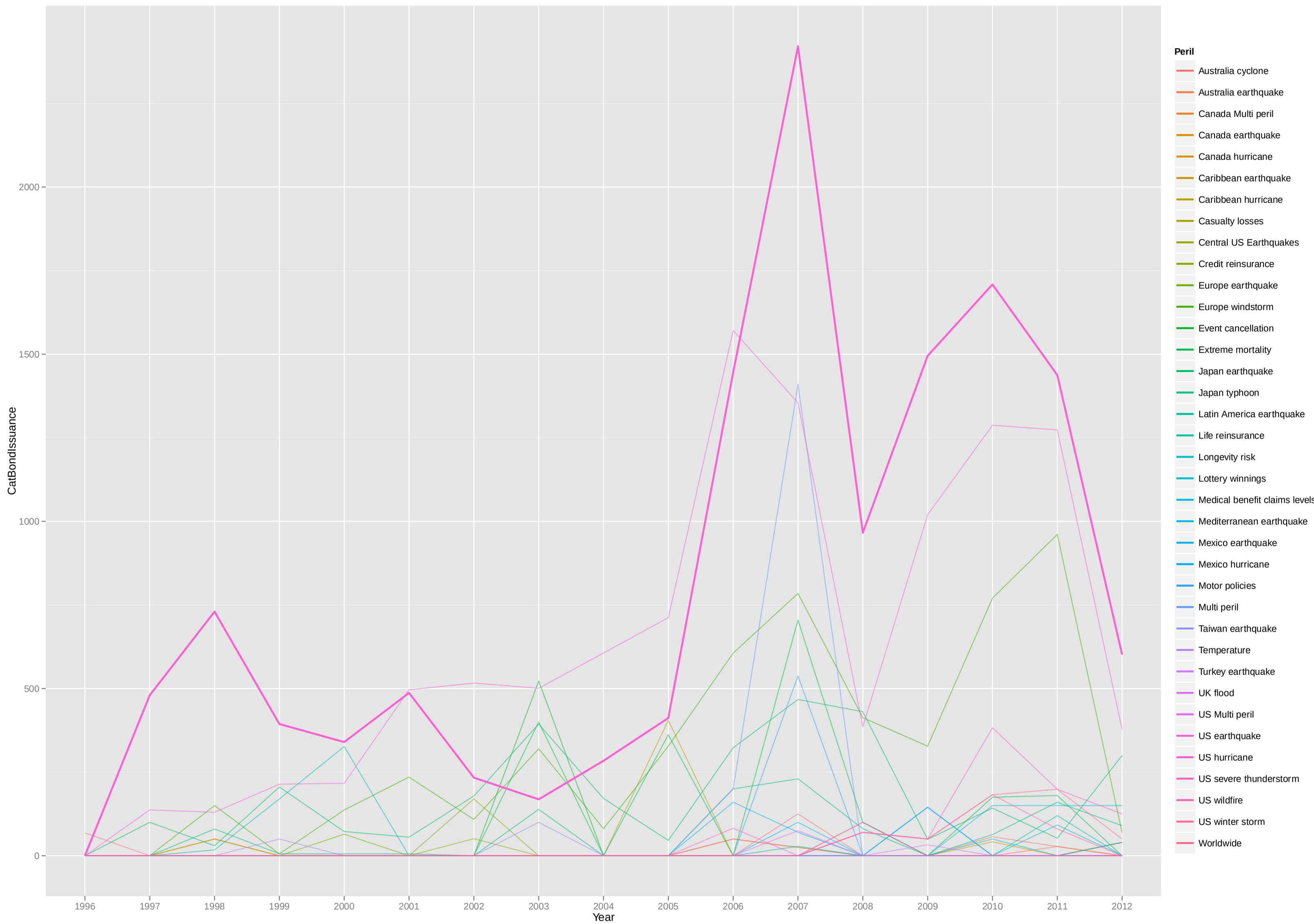


Figure 3.11: Catastrophe bond issuance based on Artemis.bm's Catastrophe Bond Deal Directory with analysis by author

Given the concentration of hurricane risk in reinsurance portfolios, economic theory suggests that reinsurers should be excited by the opportunity to hold positions that are not highly correlated to hurricanes, particularly in a market where they feel they have expertise.

But ENSO wouldn't be just an uncorrelated market. It would be a negatively correlated market, actually offsetting hurricane risk. Climatological studies suggest that landfalls of major hurricanes along the east coast of the United States and the Caribbean are historically less likely during El Niño years than during normal ENSO phase or La Niña conditions Gray (1984a) Gray (1984b) Wilson (1999) Klotzbach (2011). This result, corroborated by repeated studies of different data sets spanning three decades, means that reinsurers selling El Niño protection will be paying out on contracts in years where their hurricane losses are light and receiving payments in years where the rest of their portfolios are suffering.

The EM-DAT database includes 616 separate catastrophic storm events between 1960 and 2010 impacting North America and the Caribbean between the months of June and November (the traditional hurricane season). The median damage across the region for each hurricane season is roughly USD 10.5 b, many times larger than for floods in Southeast Asia and Oceania, or Pacific South America. Economic damage estimates for all weather-linked disaster types across the region is displayed alongside the ONI index in figure 3.12. No clear trends are visible in the raw data, apart from a rise in the average damages due to flooding and storms.

The Phillips-Perron Unit Root test favored stationarity for both time series (for the index and damages as a percent of the seasonal median) with 95 percent confidence. The Augmented Dickey Fuller Test found a p-value of 0.05 for the damage series. Neither time series showed significant autocorrelation using a standard autocorrelation function.

Based on Klotzbach (2011) I created an ENSO index for hurricanes by averaging ONI index values between August and October for any given year (e.g. the 2010 hurricane season spanning June through November 2010 is matched with the average ONI index values for August through October 2010.) I then regressed hurricane damages on the seasonal ONI index average as in equation 3.3. Distinct from the other risk-regions analyzed in this chapter, I estimated regression coefficients both for the individual ENSO phases (e.g. $a_{\text{La Niña}}$, a_{normal}, $a_{\text{El Niño}}$) and for all ENSO phases pooled together (e.g. a_{pooled}). A pooled regression only makes sense in this case because previous literature suggested that there may be a straight-forward inverse relationship between ENSO and hurricanes, with high ENSO values producing low levels of hurricane damage and visa-versa.

The pooled and normal coefficients were given uninformative priors while the El Niño and La Niña coefficients were given priors based on Klotzbach (2011), Bove et al. (1998), and Pielke Jr and Landsea (1999). Klotzbach (2011) found that average number of major hurricanes per year for El Niño years was 1.5, compared to 2.1 for years when ENSO was in a normal phase. Bove et al. (1998) suggest that the ratio of probabilities of a major US landfall in El Niño was 23 percent versus 58 percent in normal years. Finally, Pielke Jr and Landsea (1999) suggested that the mean damage

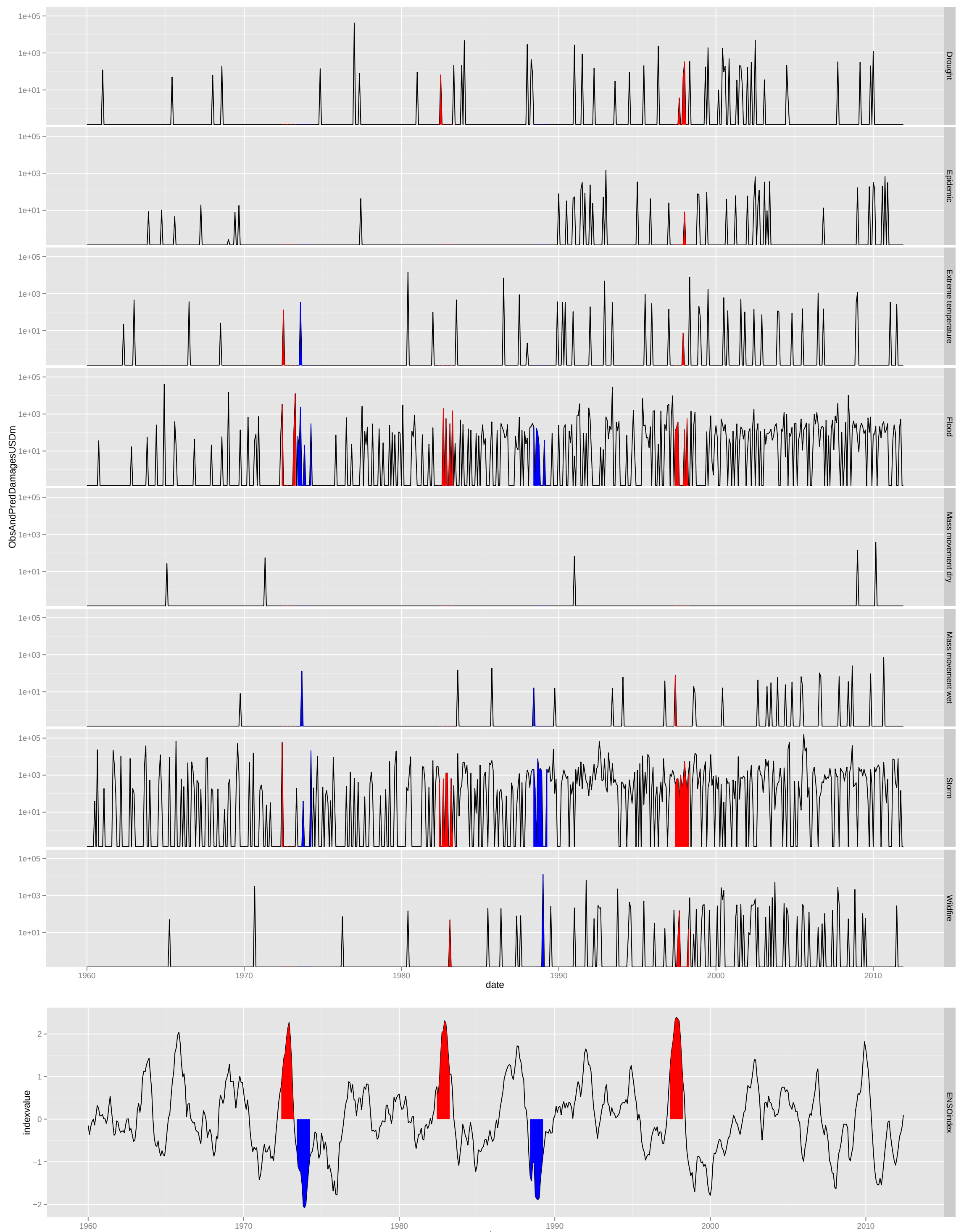


Figure 3.12: Disaster damage estimates by disaster type for countries in North America and the Caribbean compared to ENSO (ONI) index

in El Niño seasons was USD 1997 2.0 b compared to 6.9 b for normal seasons.[9] So given that three studies agreed that the burden of major hurricanes was roughly a third of its normal value in El Niño years[10], I constructed a prior that would put an average El Niño event (roughly an ONI index of 1.2) at a level of damage that was one-third the median across all seasons. I further constrained that prior so as to avoid making the prior so steep as to suggest no damage for an ONI index of 3 (larger than any on record but well within the realm of possibility).

The three studies showed similar agreement for La Niña. Klotzbach (2011) suggested that the average La Niña season has a hurricane burden two-thirds that of a normal season. Bove et al. (1998) and Pielke Jr and Landsea (1999) found that the average La Niña season has hurricane burden slightly lower than that of a normal phase season. Based on those studies, I constructed a prior suggesting that the average La Niña season (an ONI value of roughly -1.2) had damages that were between one-third higher than the median and one-half of the median. Both these sets of priors are highly informative. I believe that informative priors are justified by the concurrent findings of previous climate research on separate databases.

$$
\begin{array}{lcl}
\log \text{Jun-Nov damage as percent of median}_{yeart} & \sim & \mathcal{N}(\hat{y}_i, \sigma_y^2) \\
\hat{y}_i & = & a_{\text{Niño phase}} \\
 & & +b_{\text{Niño phase}}* \\
 & & \text{mean Aug-Oct ONI index}_{\text{year t}} \\
a_{\text{pooled}} & \sim & \mathcal{N}(1, 1000) \\
a_{\text{La Niña}} & \sim & \mathcal{N}(1, 1.75^2) \\
a_{\text{normal}} & \sim & \mathcal{N}(1, 1000) \\
a_{\text{El Niño}} & \sim & \mathcal{N}(0, 0.5^2) \\
a_{\text{pooled}} & \sim & \mathcal{N}(0, 1000) \\
b_{\text{La Niña}} & \sim & \mathcal{N}(-0.66, 1.25^2) \\
b_{\text{normal}} & \sim & \mathcal{N}(0, 1000) \\
b_{\text{El Niño}} & \sim & \mathcal{N}(-0.13, 0.4^2) \\
\sigma_y^2 & \sim & \mathcal{U}(0, 100)
\end{array}
\tag{3.3}
$$

Table 3.3 provides the output of the regressions in equation 3.3. The grouped regression suggests the opposite of what I expected to find - a slightly positive slope coefficient. For the phase-specific regressions, a slope coefficient of 0 is well within the 95 percent probability interval for all three phases, suggesting no clear relationship between changes in the ONI index and storm damages in EM-DAT. However, the intercept parameter for El Niño is likely below that for normal ENSO phase seasons. The El Niño and normal phase intercept parameters begin to overlap at the 94 percent and 6 percent quantiles respectively, suggesting that they are distinct with 88 percent probability.

[9] Note that Pielke Jr and Landsea (1999)'s median damage estimate, made in 1997, is well below the current USD 10.5 b suggested by EM-DAT.

[10] Note that the studies used slightly different definitions of El Niño.

Table 3.3: Diagnostics for Bayesian regression of economic damages in North America and the Caribbean from June to November on ONI August to October average

grouped	observed seasons	51							
	mean	sd	2.50%	25.00%	50.00%	75.00%	97.50%	$\hat{R}$	n.eff
a	1.931	0.472	1.009	1.615	1.931	2.245	2.876	1.0012	6300
b	0.454	0.561	-0.657	0.084	0.457	0.825	1.552	1.0009	11000
sigma.y	3.357	0.348	2.769	3.112	3.326	3.569	4.130	1.0012	5300
La Niña	observed seasons	6							
	mean	sd	2.50%	25.00%	50.00%	75.00%	97.50%	$\hat{R}$	n.eff
a	0.984	1.214	-1.381	0.176	0.975	1.800	3.341	1.0012	6800
b	-0.194	0.941	-2.040	-0.829	-0.186	0.440	1.652	1.0010	11000
sigma.y	1.374	0.659	0.662	0.958	1.211	1.592	3.032	1.0011	10000
Normal	observed seasons	39							
	mean	sd	2.50%	25.00%	50.00%	75.00%	97.50%	$\hat{R}$	n.eff
a	1.940	0.593	0.776	1.552	1.934	2.328	3.112	1.0009	11000
b	0.310	1.185	-2.036	-0.478	0.312	1.073	2.637	1.0011	9000
sigma.y	3.706	0.449	2.951	3.388	3.662	3.982	4.692	1.0011	9100
El Niño	observed seasons	7							
	mean	sd	2.50%	25.00%	50.00%	75.00%	97.50%	$\hat{R}$	n.eff
a	0.259	0.493	-0.702	-0.070	0.268	0.590	1.219	1.0011	9300
b	0.131	0.390	-0.661	-0.125	0.142	0.394	0.886	1.0014	3900
sigma.y	4.142	1.656	2.174	3.071	3.785	4.768	8.262	1.0010	11000

Figures 3.13 and 3.14 provide a more complete picture of the regression findings. Even with strong guidance from previous studies, the regional damage data in EM-DAT remains noisy and involves too few observations from La Niña and El Niño years to provide a strong inference about hedging interest on an ENSO exchange. However, damages are likely lower in El Niño years than during the normal ENSO phase.

On average, the estimated losses for a modest El Niño season (August through October ONI index average) are roughly 40 percent of the median across all seasons (USD 10.5 billion). Given the magnitude of median losses, this is a difference that, while not statistically significant with 95 percent probability, is of great economic importance. Given a 40 percent drop in hurricane damage during El Niño season, the reinsurance industry should gladly act as counter-party for any firm looking to purchase El Niño protection on a futures or options market. Their windfall due to the drop in hurricane damages should be enough to cover the full range of estimated impacts on South America's Pacific costs (USD 2.2 to 4.7 billion) generated by an extreme El Niño.

3.7 El Niño drought regions - Southern Atlantic, Indian Ocean basin, East Asia, Oceania

El Niño is associated with drought and wildfire across large swaths of the globe. In this analysis I grouped disaster data from all the regions strongly suspected of suffering from El Niño related drought. That includes most of of the Indian Ocean Basin, as well as the region most associated with La Niña flooding, Pacific East Asia and Oceania. It also includes the Brazil and the countries of the Sahel. See the damage time series for this region is displayed along side the ONI index in figure 3.15 for details.

There are 299 droughts and wildfires in the EM-DAT database corresponding to this group of countries, with a median September through August (the same benchmark months used to measure flooding in Pacific Asia and Oceania) damage due to drought and wildfire of USD 1.7b. Each season's damage corresponded to average ONI index values measured between October and January of that damage season.

I performed the Augmented Dickey-Fuller Test and the Phillips-Perron Unit Root Test on the damage time series. (See the Pacific South America section for results from the corresponding index time series.) Both tests favored the alternative hypothesis of stationarity with greater than 95 percent confidence. The time series showed no significant autocorrelation using a standard autocorrelation function.

Dai et al. (1998) used a linear regression to describe the relationship between ENSO and drought across many regions of the world, without segregating the dataset into its constituent ENSO phases. I follow that convention here, presenting a single grouped regression, as in equation 3.4, rather than a series of regressions. To the extent that I believe (based on Dai et al. (1998)) that the relationship between ENSO and drought in these countries can be represented by a single line, then I prefer a single regression because that would maximized the number of observations in the sample.

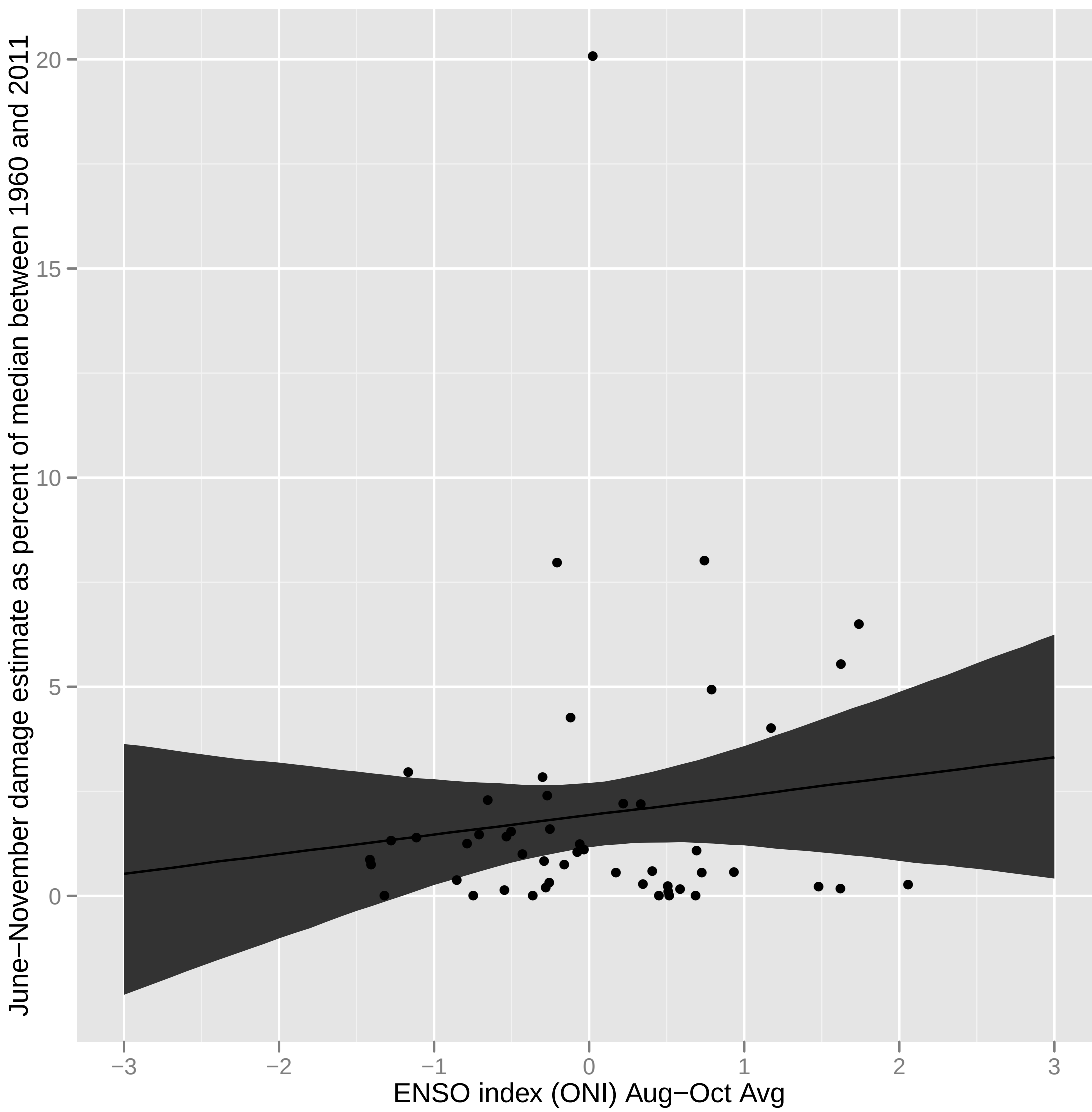


Figure 3.13: Bayesian regression analysis of damage estimates from storms and flooding in North America and the Caribbean predicted by ENSO index, pooled across ENSO phases

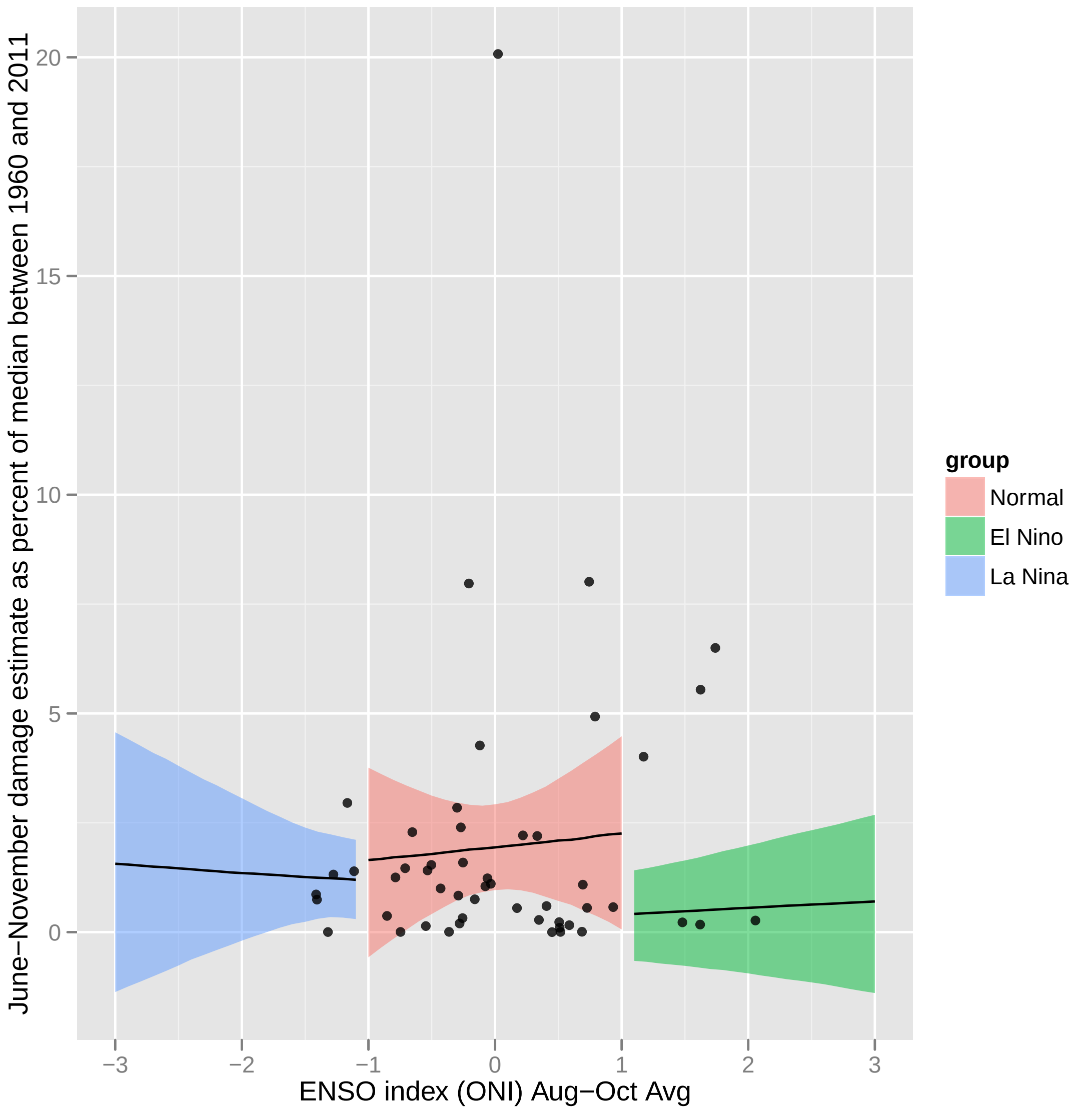


Figure 3.14: Bayesian regression analysis of damage estimates from storms and flooding in North America and the Caribbean predicted by ENSO index, separate regressions for each ENSO phase

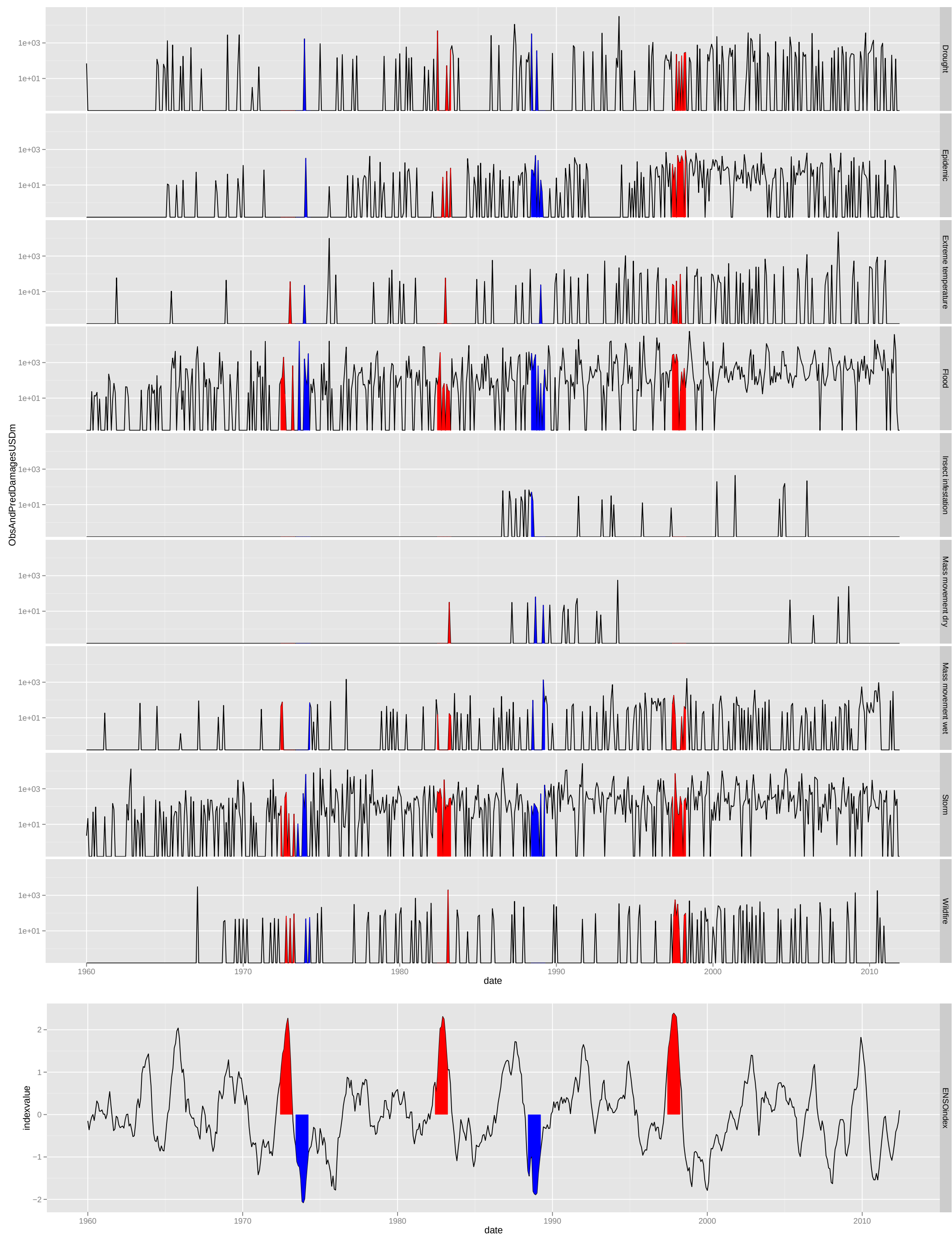


Figure 3.15: Disaster damage estimates by disaster type for countries in regions that are suspected to experience drought during El Niño events compared to ENSO (ONI) index

The priors I chose for the regression are based on figure 3.16 which suggests that between 1979 and 1995, an El Niño with a severity that is two standard deviations away from the average, caused the burden of drought across the world to be approximately 1.75 standard deviations above its average, over the full period of study. Between 1900 and 1978 that same magnitude El Niño was associated with drought burden approximately 1.5 standard deviations above the sample average. Assuming that the drought index used in the study is a reliable proxy for drought in my sample, I used the standard deviation from the sample to translate these observations from Dai et al. (1998), along with observations for the intercept of each regression line, into a likely range for the parameter values in my regression. I doubled the standard deviation of the prior relative to the standard deviation suggested by the range in figure 3.16 to allow additional flexibility in the regression. The resulting priors are presented in equation 3.4

$$\begin{aligned}
\log \text{Sep-Aug damage as percent of median}_{yeartthought+1} &\sim \mathcal{N}(\hat{y}_i, \sigma_y^2) \\
\hat{y}_i &= a \\
&\quad +b* \\
&\quad \text{mean Oct-Jan ONI index}_{\text{year t-1 thro}} \\
a &\sim \mathcal{N}(2.625, 3.25^2) \\
b &\sim \mathcal{N}(1.8, 2.5^2) \\
\sigma_y^2 &\sim \mathcal{U}(0, 100)
\end{aligned} \tag{3.4}$$

The output from those regressions in table 3.4, place a slope coefficient of 0 well within the 95 percent probability interval. (See figure 3.17 for more detail.) This indicates that despite informative priors, the data in the EM-DAT database are too noisy to discern any relationship between ENSO and drought in these regions. The median economic burden of drought on the region is modest relative to those of the other peril/region groups studied here, so not only is the relationship statistically weak, but it is also of less economic consequence than the other relationships analyzed in this chapter.

Based on this regression I have decided against including economic damage from likely El Niño drought regions in my estimate of hedging interest for an exchange traded ENSO market.

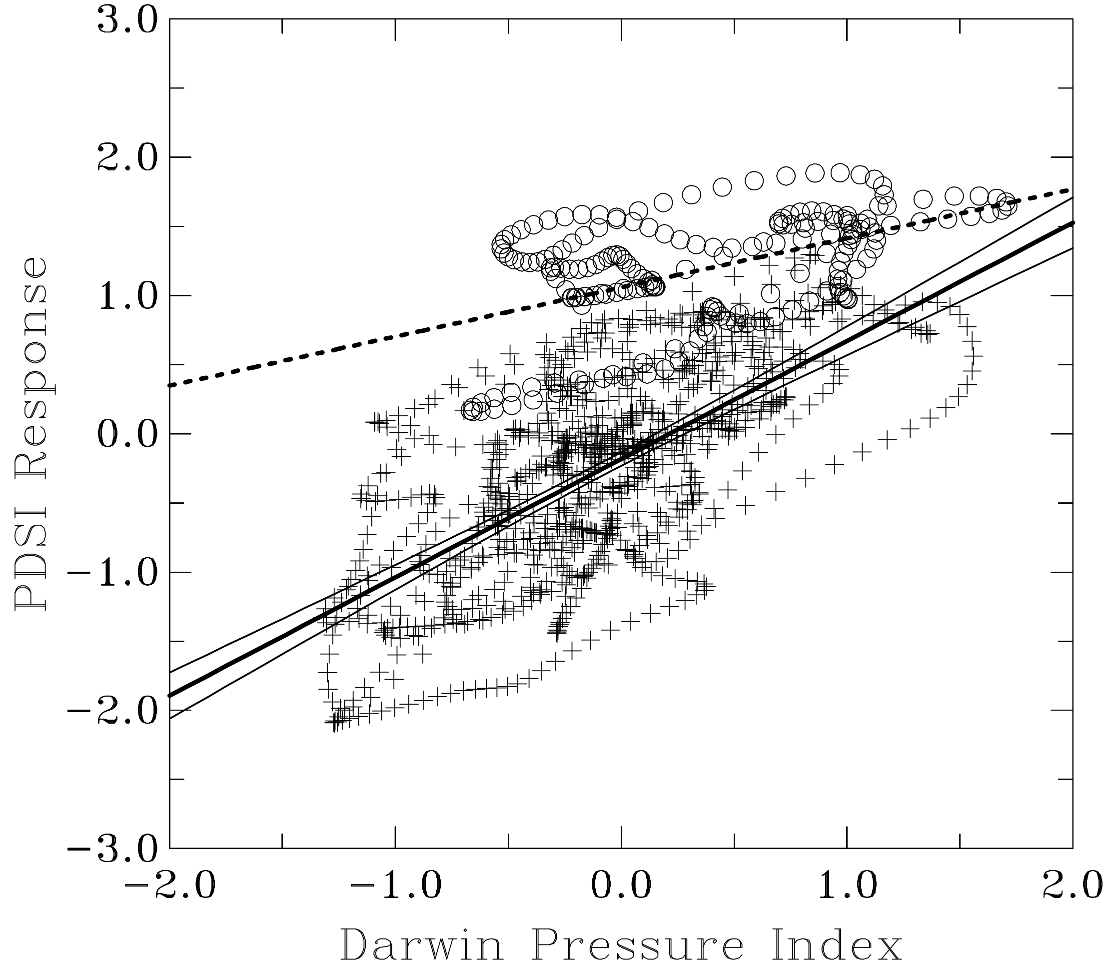


Figure 3.16: Reprinted from Dai et al. (1998) - a scatter plot of the first eigenvalue of the Empirical Orthogonal Function for a common drought index, the Palmer Drought Severity Index (PDSI) (response) plotted across the world versus the Darwin pressure index (a measure of ENSO strength) from six months previous. The crosses are monthly data points for 1900-1978 and the circles are for 1979-1995. The thick solid line is the linear regression for 1900-1978 and the thin lines are the 99% confidence intervals. The dashed line is the regression for 1979-1995.

Table 3.4: Diagnostics for Bayesian regression of economic damages in North America and the Caribbean from June to November on ONI August to October average

All ENSO phases	Observed seasons	51							
	mean	sd	2.50%	25.00%	50.00%	75.00%	97.50%	$\hat{R}$	n.eff
a	1.660	0.399	0.869	1.399	1.658	1.926	2.453	1.0009	11000
b	0.295	0.382	-0.455	0.039	0.290	0.548	1.056	1.0010	11000
sigma.y	2.916	0.303	2.390	2.704	2.893	3.097	3.599	1.0013	4300

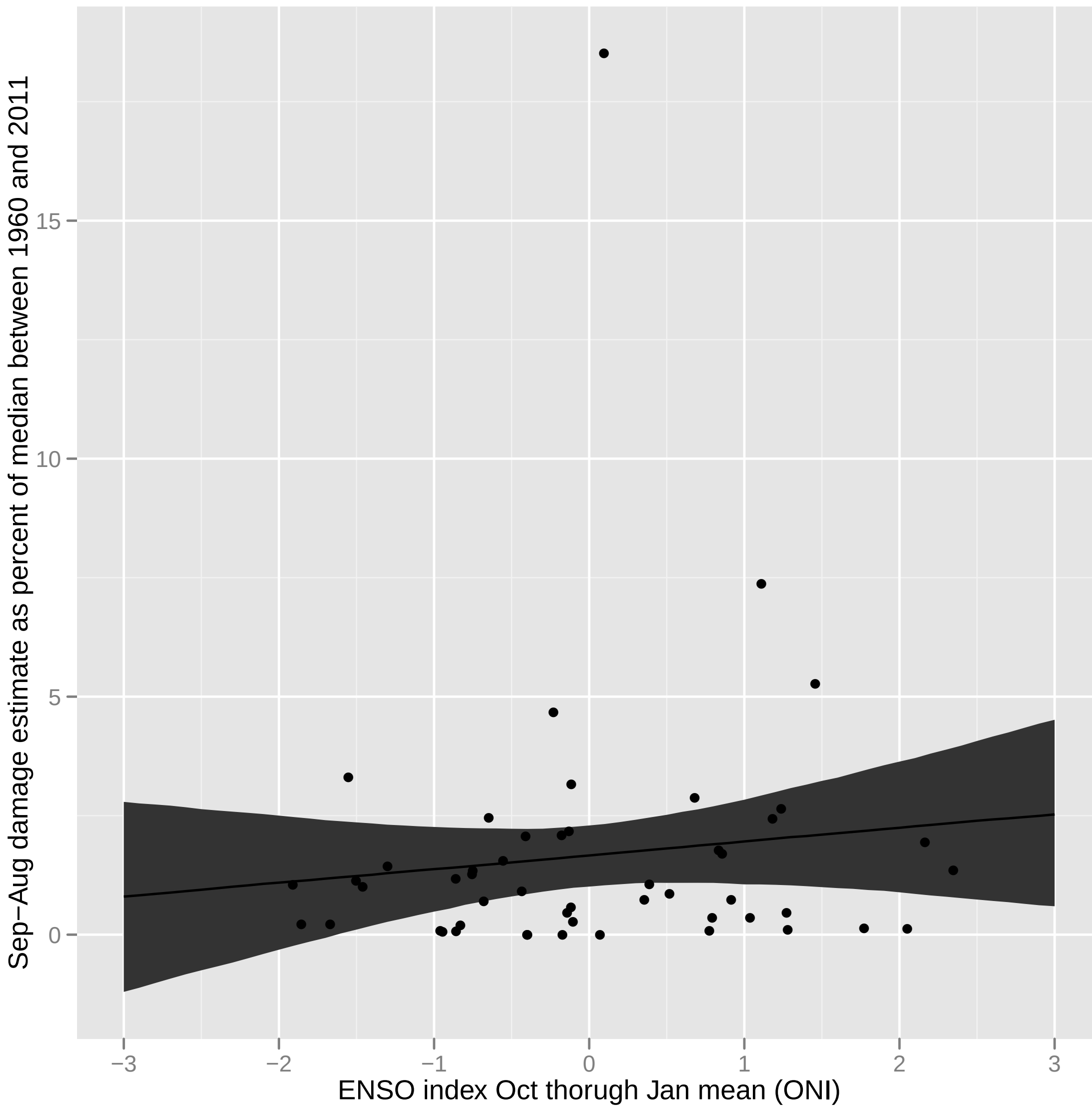


Figure 3.17: Bayesian regression of drought and wildfire damages estimates from likely El Niño drought regions, 1960-2011 predicted by ONI index

3.8 How do these markets compare to other widely traded commodities?

This statistical analysis approximates the hedging interest that could be generated on ENSO markets. The analysis deals exclusively with disaster damages - so my estimate of hedging interest is confined to the measurable losses that might otherwise be managed with insurance (e.g. a firm purchases a futures contract so that they have funds to rebuild critical infrastructure after a major anomaly). It does not cover the hedging interest that will come from firms or institutions using, for example, ENSO derivatives as a diversified asset that can improve their underlying portfolio of business. In other words, whereas my initial hedging interest estimate is based off of expected losses, much, perhaps most, of the hedging interest on a successful teleconnection index exchange will stem from firms and individuals anticipating lost opportunities.

Table 3.5: Regression estimates of extreme ENSO events indicative of hedging interest (damages in USD b)

Index/anomaly	Pr(event)	Peril	Region	Window	Median seasonal damage	Damage from large event	E[Damage (lg event)]
ENSO							
El Niño							
ONI index ≥ 2	0.075					for ONI $= 2$	
		Flood/ landslide/ epidemic	South America	Jan-Jun	0.259	3.4	0.257
		Storms	North America/ Caribbean	Jun-Nov	10.5	5.4	0.410
					from median	-5.0	-0.377
La Niña							
ONI index $\leq$ -1.85	0.05					for ONI $= -1.85$	
		Flood	Asia/Oceania	Sep-Aug	3.07	8.0	0.401

Table 3.5 presents aggregate findings from the damage regressions for historically large ENSO anomalies. These estimates are meant to provide general guidance about the hedging interest that might be generated by individual large anomalies, conditional on their occurrence and weighted by their approximate historical probability.

Based on these results, ENSO anomalies, both high and low, could generate hedging interest in the range of a few billion dollars. The estimates are particularly promising for futures and options markets because they show a rough balance between interest in El Niño and La Niña coverage.

The damage associated with El Niño flooding in South America is entirely offset by a combination of savings to the insurance industry from El Niño's inverse correlation to Atlantic tropical storm damage and interest in hedging La Niña risk from Pacific Asia and Oceania. In fact, hedging interest may concentrate on the La Niña side of the market, although this is difficult to assess without additional analysis of damages in the regions likely to suffer from droughts during El Niño.

Of course, the figures for ENSO in table 3.5 are more valuable relative to a benchmark showing how similar analyses would apply to the indexes underlying successful futures and options contracts. In table 3.7, I present estimates of the impact of one and two standard deviation falls in the annual average crop price index from the US Department of Agriculture in terms of the percentage change in the total value of the US's annual crop for corn, wheat, and soybeans National Agricultural Statistics Service (2012).[11] These benchmarks place ENSO risk in the context of indexes that are already the basis of successful exchange-traded derivatives markets.

For the sake of comparison, I've included a similar table coving anomalies in the Arctic Oscillation (AO) in table 3.6. The analysis underlying those benchmarks is available in Arctic Oscillation (AO).

The regressions indicate that large anomalies in ENSO and AO indexes could generate hedging interest of a comparable magnitude to large changes in price indexes for major US crops. It is difficult to compare risks as distinct as price changes in corn and extreme El Niño. But tables 3.5, 3.6, and 3.7 show that events that would be considered "extreme" (approximately two standard deviation events) in both AO and ENSO indexes are comparable to two standard deviation events in major crop price indexes, both in terms of absolute and expected losses.

[11]The figures in table 3.7 come from regressions of annual percentage changes in each index (price and production value) which are not discussed here.

Table 3.6: Regression estimates of extreme AO events indicative of hedging interest (damages in USD b)

Index/anomaly	Pr(event)	Peril	Region	Window	Median seasonal damage	Damage from large event	E[Damage (lg event)]
AO							
Low							
$-3.5 < \text{AO index} \leq -3$	0.025					for AO $= -3$	
		Storms/ extreme temps	Countries/ with territory above 45°N	Dec	0.181	1.8	0.045
				Jan	0.674	6.7	0.1675
				Feb	0.165	1.6	0.04
				Mar	0.202	2	0.05
				Dec-Mar	1.222		0.3025
AO index ≤ -3.5	0.01					for AO $= -3.5$	
		Storms/ extreme temps	Countries/ with territory above 45°N	Dec	0.181	2.3	0.0575
				Jan	0.674	8.5	0.2125
				Feb	0.165	2.1	0.0525
				Mar	0.202	2.6	0.065
				Dec-Mar	1.222		0.3875

Table 3.7: Regression estimates of change in total annual US crop value (1908-2011) based on percentage price change (USD b), for approximately one and two standard deviation moves.

Index/anomaly	Pr(event)	Fall in annual production value	E[Fall]
Corn, % change in price received			
23% $\leq$ percentage fall <46%	0.12	23% fall from the 2011 price 3.752	0.45024
percentage fall $\geq$ 46%	0.1	46% fall from the 2011 price 7.504	0.7504
Wheat, % change in price received			
18% $\leq$ percentage fall <36%	0.22	18% fall from the 2011 price 2.018	0.44396
percentage fall $\geq$ 36%	0.05	36% fall from the 2011 price 4.037	0.20185
Soybean, % change in price received			
17% $\leq$ percentage fall <34%	0.24	17% fall from the 2011 price 2.985	0.7164
percentage fall $\geq$ 34%	0.06	34% fall from the 2011 price 5.971	0.35826

Chapter 4

Pricing ENSO Derivatives

In chapter 3 I showed that ENSO is associated with the volume and patterns of economic damage that may justify active trading. This chapter estimates how much ENSO risk protection costs. As part of that estimate, this chapter includes:

- an introduction to data quality issues surrounding ENSO;
- month-by-month analysis of the long-term average index values that could be used to price insurance against catastrophic El Niño/La Niña;
- modeling and analysis that links emerging ENSO forecasts to index values;
- futures and options prices conditional on ENSO forecasts (see the pricing appendices D through O) for full conditional prices by month); and,
- suggestions about how those theoretical prices will be modified for actual trading.

All the pricing routines presented in this chapter are based on the data available[1] at:

- `http://www.cpc.ncep.noaa.gov/data/indices/ersst3b.Ni˜no.mth.81-10.ascii`
- `http://www.cpc.ncep.noaa.gov/data/indices/sstoi.indices`

The forecasts used for conditional pricing in this chapter come from Colombia University's International Research Institute for Climate and Society (IRI). The archive of those forecasts is available[2] at:

- `http://iri.columbia.edu/climate/ENSO/currentinfo/archive/`

4.1 Understanding NOAA's SST indexes

NOAA publishes two primary sea surface temperate indexes. By and large, those indexes tell the same story about El Niño/La Niña. However, they are compiled with different methodologies, over different horizons. Understanding those distinctions is an important first step in pricing El Niño/La Niña risk protection, especially insofar as it suggests challenges to reliable contract settlement.

[1]. . . as of May 2013
[2]. . . also as of May 2013

NOAA's Extended Reconstructed Sea Surface Temperature Index (ERSST) dataset provides a longer record, while NOAA's Optimum Interpolation Sea Surface Temperature Index (OISST) offers finer resolution. As I discuss below, my analysis in this chapter is focused on ERSST data, because OISST's limited horizon (the index begins in the early 1980s) may unfairly bias derivative and insurance prices upward.

NOAA's Extended Reconstructed Sea Surface Temperature Index (ERSST)

Most of the pricing in this chapter uses the latest iteration of NOAA's older ENSO-related SST index, ERSST version 3b. The key factor distinguishing ERSST from OISST is the use of in-situ and satellite data. With the exception of version 3[3], all the ERSST iterations (1,2, and 3b, the iteration used here) use in-situ measurement exclusively (Smith and Reynolds, 2004) (Smith and Reynolds, 2003) (Smith et al., 2008). The full methodology for ERSST version 3b is described in detail in Smith et al. (2008)[4].

Monthly anomalies in the ERSST version 3b index are measured relative to a 1971-2000 base period (Xue, Smith, and Reynolds, 2003). NOAA releases monthly ERSST estimates with a resolution of two degrees across the four ENSO regions. While the primary index record that NOAA posts to its websites goes back to 1950, monthly ERSST data are available from 1854 on.

Historically, all in-situ measurements came from passing ships. Smith and Reynolds (2004) suggests that ship-based measurements pose challenges to researchers:

> . . . the historic distribution of in situ SST data from ships has varied with time due to a variety of economic and political changes (the opening of new canals, world wars, improved communication, etc.). In addition, biases in the ship in situ data have occurred as observational techniques have changed, and those biases must be corrected [statistically] . . .

The last decades' in-situ records have relied more heavily on dedicated buoys, as Reynolds et al. (2002) describes:

> SST observations from drifting and moored buoys were first used in the late 1970s. Buoy observations became more plentiful following the start of the Tropical Ocean Global Atmosphere (TOGA) program in 1985 (McPhaden et al., 1998).[AUTHOR'S NOTE: This program began as a response to the 1982/1983 El Niño event.] These observations are typically made by thermistor or hull contact sensor and usually relayed in real time by satellites. Although the accuracy of the buoy SST observations varies, the random error is usually smaller than 0.5 °C and, thus, is better than ship error. In addition, typical depths of the measurements are roughly

[3]ERRST version 3 included infrared satellite data starting in 1985. NOAA determined that this addition introduced some biases into the index - it tended to suggest temperatures that were too cold by a factor of .01 deg C. NOAA consequently removed satellite data (although it retains in situ data collected via satellite) from the calculation of ERSST version 3b, the current standard.

[4]Note that this citation is actually for version 3

> 0.5 m rather than the 1 m and deeper measurements from ships. ... [The] deployment of the buoys has been designed to fill in some regions with few ship observations. This process had the most impact in the tropical Pacific Ocean and the Southern Hemisphere.

Given the improvements to the SST record over time, someone pricing risk management contracts using ERSST might want to give different weights to different eras in the historical record. However, the period since 1970 has had a much greater incidence of extreme El Niño/La Niña events than any other in the historical record. So, prices that rely more heavily on recent data will almost certainly be more expensive.

NOAA's Optimum Interpolation Sea Surface Temperature Index (OISST)

By the early 1980s, in-situ measurements were complemented by direct satellite measurements. Again, Reynolds et al. (2002) explains:

> In late 1981, Advanced Very High Resolution Radiometer (AVHRR) satellite retrievals improved the data coverage over that of in situ observations alone. The satellite retrievals allowed better resolution of small-scale features such as Gulf Stream eddies. Because the AVHRR cannot see the surface in cloud-covered regions, the biggest challenge in retrieving SST is to eliminate cloud contamination

This satellite data became the basis of NOAA's alternative to ERSST, the Optimum Interpolation Sea Surface Temperature Index (OISST). NOAA releases OISST data weekly on a one-degree grid across the key ENSO regions. So it is available more often, and on a finer scale, than ERSST.

OISST, currently at version 2, combines in situ SST measurements, daytime and nighttime satellite data readings, and data from sea ice cover simulations. The satellite data is adjusted statistically for natural sources of bias, like cloud cover and atmospheric water vapor (Reynolds et al., 2002) (Reynolds and Smith, 1994) (Reynolds and Marsico, 1993) (Reynolds, 1988).

4.2 Additional dataset considerations

After picking a dataset for pricing, you must also decide on the region to price, whether to use absolute SST measurements (°C) or anomalies, and any other data cleaning routines, like adjusting the standard deviation to match recent decades. In this section I walk through those considerations and settle on a baseline for pricing of:

- Niño 3.4;
- measured in absolute degrees Celsius;
- without any standard deviation adjustments.

Niño region

As discussed in chapter 3, the Niño 3.4 region (figure 3.4) is the de facto benchmark for identifying El Niño/La Niña events world wide. It is consequently the basis of the pricing below.

In chapter 3, I also discussed the relative merits of Niño 1.2, the region with the tightest connection to Peruvian flooding, which GlobalAgRisk used for its El Niño insurance. The main disadvantages of that index are:

- Niño 1.2 anomalies arise later in the year, so the index has a smaller window for advanced payments; and
- Niño 1.2 may do poor job of representing El Niño/La Niña events with the same geographic signature as the 1972/1973 El Niño - where warming was focused on the central Pacific.

If Niño 1.2 is the best proxy for Peru, does that mean that Niño 4, on the other side of the Pacific, is the best proxy for Australia. Andrew Watkins of the Australian Bureau of Meteorology (ABM) suggests no. Both indexes represent Australian risk quite well. So, unlike Niño 1.2, Niño 4 is unlikely to find a niche of devoted specialized hedgers.

Anomalies vs. absolute SST measurements

NOAA releases each of its datasets as departures from monthly averages (anomalies) and absolute degrees Celsius. Its not immediately clear which format is better for financial contracts.

Presenting contracts in terms of anomalies facilitates interpretation of actual El Niño/La Niña events, since most major meteorological organizations define those events in terms of persistent monthly anomalies. Indeed, many forecasts of SSTs (like those from the ABM and IRI) are only provided in terms of anomalies.

The primary disadvantage of anomalies is that they have been, and will continue to be, subject to revision as underlying SSTs drift over time. In chapter 3 I briefly discussed the possible link between climate change and higher Pacific SSTs. To the extent that such trends continue, the index may revise its baseline and the interpretation of anomalies may become less clear. The ONI index, which NOAA uses to define El Niño/La Niña already uses a rolling window for its monthly base periods.

The weather traders I interviewed for chapter 8 suggested that the temperature derivatives are currently subject to annual revision. The practice has not been a problem for traders. Nevertheless, there may be advantages to using absolute SSTs. Absolute measurements will directly incorporate any underlying shifts in the index, allowing, for example, traders to simply express theories about the long-term trends in the index. Those theories and, by proxy, the market's judgment of long-term climate change might be obscured in an anomaly-based contract.

Miscellaneous data preparation

As mentioned above, many of the strongest El Niño/La Niña events on record have happened since 1970. If you believe that the more recent record is indicative of a regime change and is likely to be a better guide to the future than all the other decades on record, then there is no problem pricing risk based on that subset of the data. However, if you believe that the clustering of anomalies in last 30 years was primarily a function of random chance, then you can use the full ERSST dataset.

If you are uncertain, then some statistical adjustment of the data may provide a middle ground. For example, you can increase the volatility in the earlier part of the ERSST record to match that from the more recent record.

4.3 Comparing and choosing a dataset to price

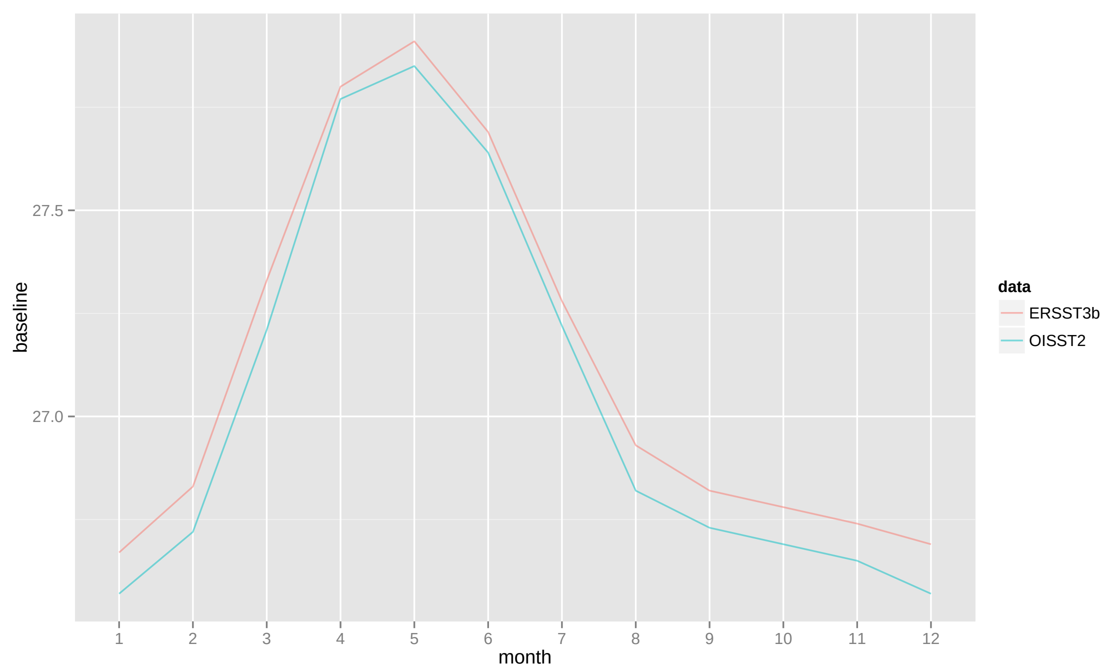


Figure 4.1: Comparing OISST and ERSST monthly baselines

Figure 4.1 provides the baseline monthly values that NOAA uses to calibrate anomalies in OISST and ERSST. Note OISSTs tendency toward colder SSTs. The cold bias in satellite data is a great concern in the climate literature and is noted in all the index construction papers on ERSST and OISST cited above.

Figure 4.1 also shows that the winter months (in the Northern Hemisphere) are the coldest in both indexes. This is interesting, given that the ENSO phenomenon takes place in the tropics and its most dramatic human impacts are in the southern hemisphere.

Finally, February/March and June/July are inflection periods, moving both indexes from cold to warm phases (the former months) and back (the latter months). The baseline SST fluctuations over these two windows is dramatic. I suspect that those months will consequently host very active trading, if traded ENSO markets launch. Those are also likely to be the months where climate expertise and proprietary data will provide the largest edge to traders. The possibility of information asymmetries in those months may undermine the volume boost that traded markets might otherwise get from increased volatility.

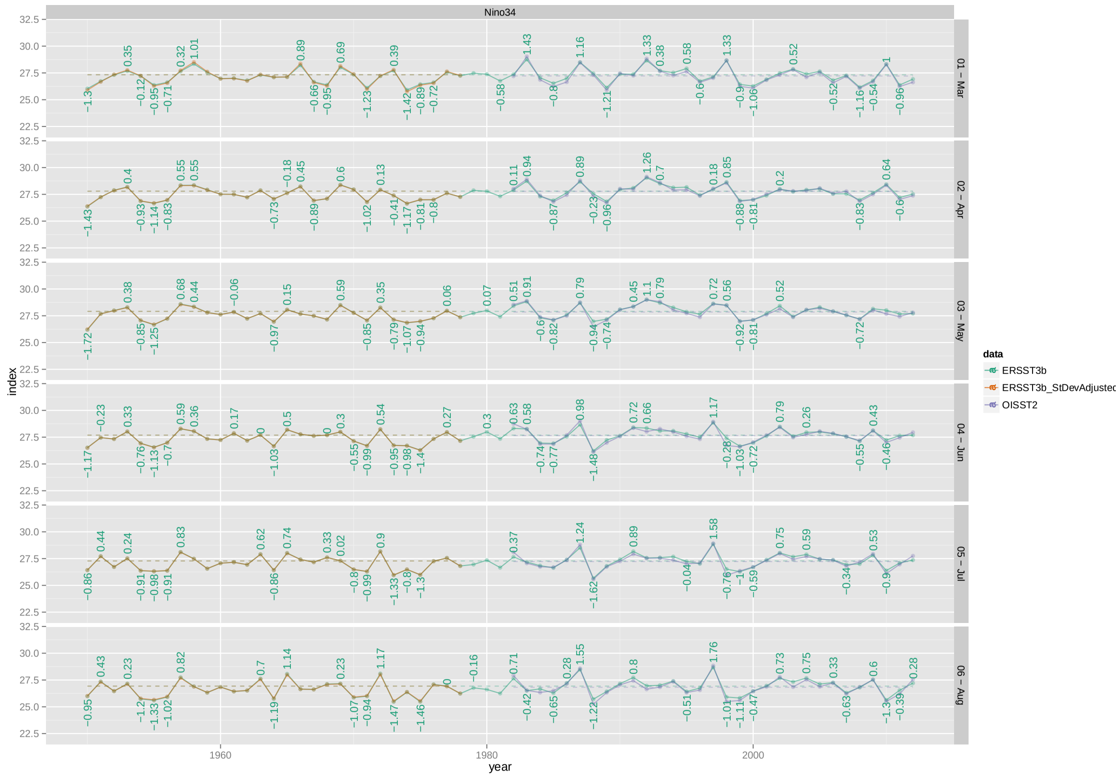


Figure 4.2: Comparing SST dataset options: March through August

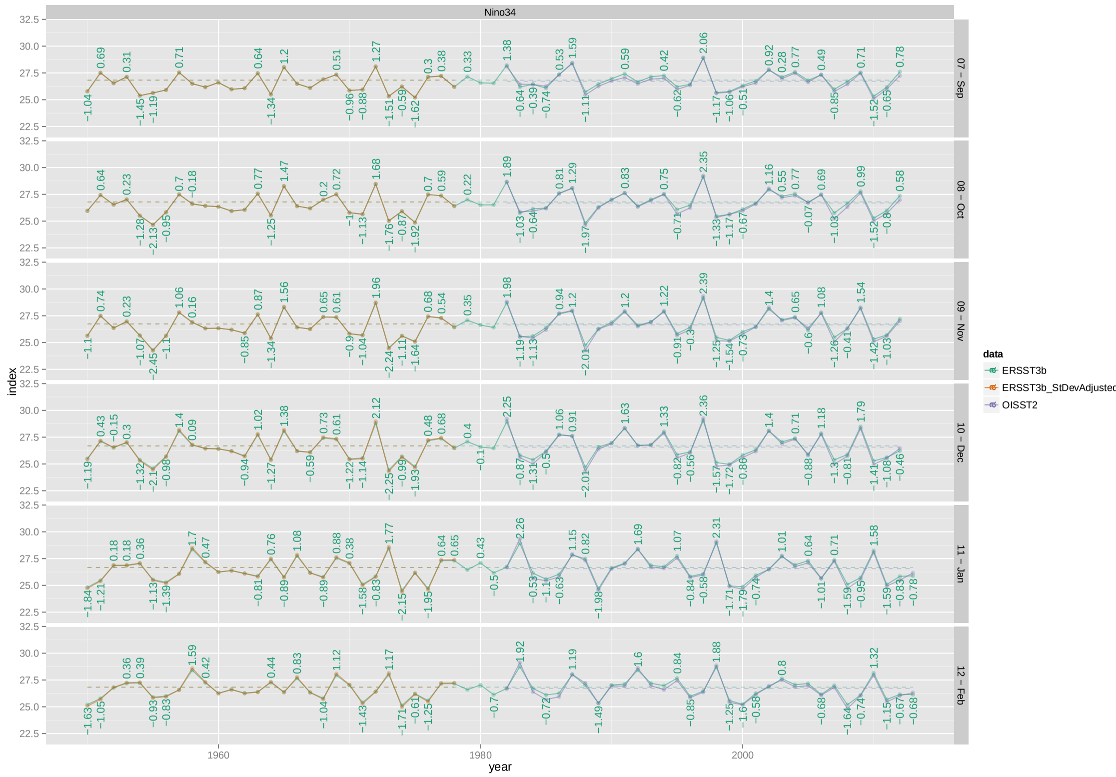


Figure 4.3: Comparing SST dataset options: September through February

Figures 4.2 and 4.3 show monthly time series for ERSST, ERSST with a standard deviation adjusted upward for pre-1979 data, and OISST. Looking at these graphs we can see a few trends that may be important in pricing risk coverage.

First and foremost, we need to look for systemic divergences between any of the indexes in the tails of their distributions, since that hedgers and speculators will be most interested in those extreme SST measurements that trigger payments. At first glance, there does appear to be a trend in tail behavior. On the La Niña side (when the indexes are in La Niña anomaly territory according to NOAA's ONI index discussed in chapter 3), OISST appears to show lower numbers than ERSST in any given month. On the El Niño anomaly side, the link is less clear. This raises the possibility that the OISST measurement has higher volatility on the cold side than on the warm side.

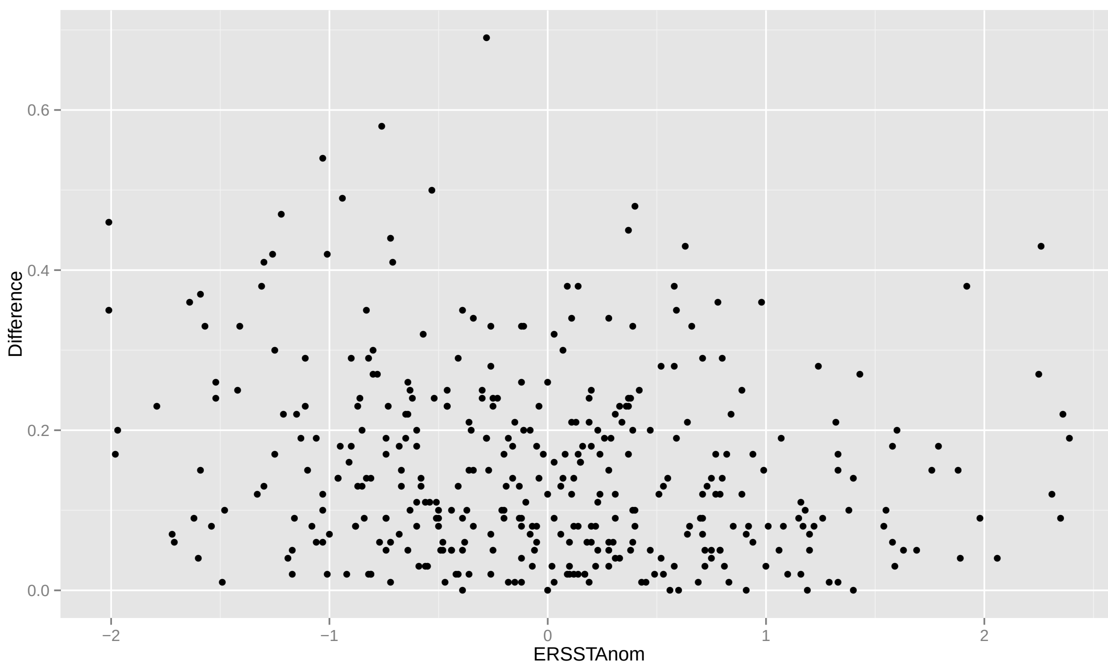


Figure 4.4: Comparing absolute value of the difference between OISST and ERSST (y-axis) and ERSST (x-axis)

Figure 4.4 is a scatter plot showing the difference between the OISST time series and the ERSST time series on the y-axis and the corresponding anomaly in the ERSST data on the x-axis. Are there patterns that suggest index choice matters a great deal in the tails of the anomaly distribution? Do the indexes agree least when we need reliable index measurements most - in a disaster?

Negative anomalies in the ERSST dataset are loosely associated with larger discrepancies between OISST and ERSST - indicated by a clump of points in the upper left-hand quadrant of figure 4.4. This is exactly what we saw in the raw time series comparison above. The implication of this trend for pricing is that simulations used for pricing OISST-based risk cover should explicitly model this downside volatility clustering.

Turning to the adjusted ERSST dataset, we see that its deviations from the basic ERSST dataset are smaller than those of OISST. Consequently, the choice between OISST vs ERSST seems more important for the ultimate pricing decision than the choice of whether or not to adjust the standard deviation of the earlier piece of the ERSST dataset.

Figure 4.5 shows the relationship between those differences and extreme values in the underlying ERSST dataset. The figure shows the distinct pattern, that the adjustment itself was intended to produce - the adjusted dataset produces its largest discrepancies when the underlying index is high. The anomalies for any given month clump in straight line patterns.

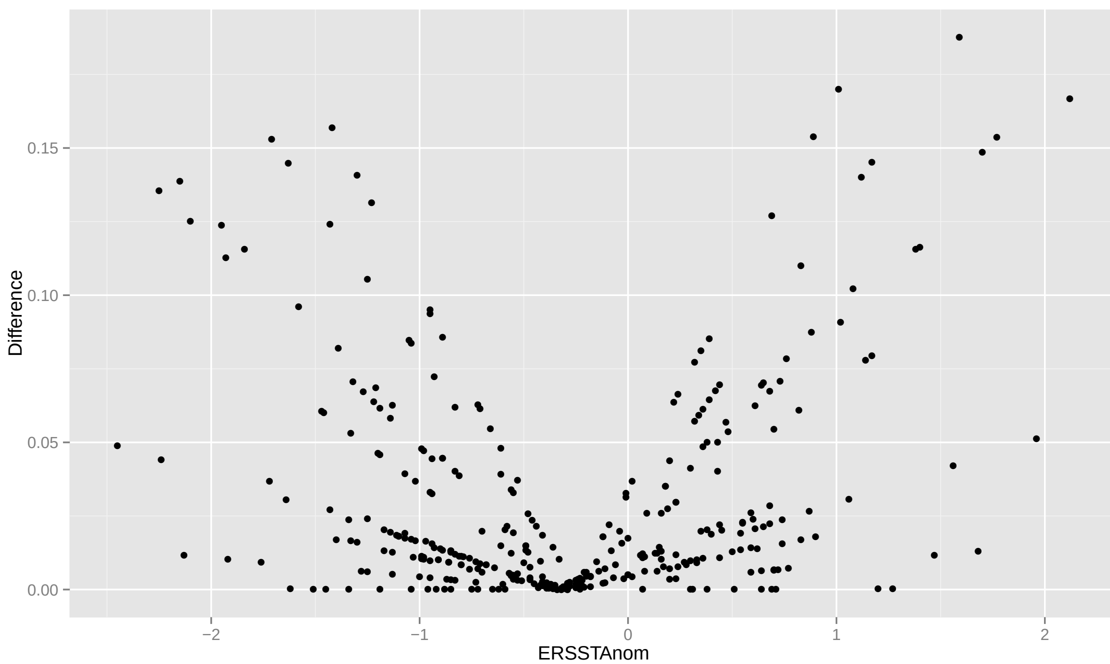


Figure 4.5: Comparing absolute value of the difference between ERSST with standard deviation adjustments and ERSST (y-axis) and ERSST (x-axis)

4.4 Arbitrage vs. expectations pricing

In a market such as corn or equities, derivatives prices come from arbitrage, buying and selling in two or more closely related markets to take advantage of a price differences across those markets. If, for example, call options on corn appear too expensive relative to today's price on spot markets, a trader can:

- sell calls (collecting a premium);

- borrow cash;
- use the cash to buy physical corn on the spot market in proportion to those calls; and
- store that physical corn.

In this case, the calls sold represent an obligation to deliver corn. But as long as the trader has corn in storage (potentially over the full term of the call option) in equal proportion to that obligation, then she can *deliver* on those calls (i.e. provide all the corn implied) at a moments' notice. This means that subsequent moves in the spot price of corn will not cause the trader to incur any additional profits or losses. All that matters to the trader is whether the premium she collected by selling her calls is greater than the cost of borrowing and storing the corn.

In an efficient market, traders specializing in arbitrage, make similar trades across all clearly linked markets. By buying corn, they nudge up the price in the physical market and by selling calls they nudge down the implied price of corn in options markets. Over time, price discrepancies between markets fall until the margins on these *risk-less*[5] trades disappear.

Black, Scholes, and Merton's Nobel-Prize-winning work on options pricing demonstrated that, given ideal conditions, the simple existence of these arbitrage strategies suggests rational option prices that do not include traders' expectations for the price of the underlying good (Black and Scholes, 1973) (Merton, 1973). In other words, you can rationally price an option that would pay if corn goes to USD 8 per bushel without guessing about the probability of corn actually going to USD 8 per bushel.

By contrast, SSTs cannot be arbitraged directly. There is no opportunity to take a chunk of the Pacific Ocean today and deliver it in the future at a pre-arranged temperature. I'll discuss later how it may be possible to piece together rough arbitrage strategies by looking at the prices of related markets, such as a basket of more localized weather derivatives. But even with those opportunities, arbitrage is not going to provide theoretically definitive ENSO derivatives prices. Instead, those prices will have to come from reasonable guesses about traders' expectations for future SST.

4.5 Pricing outside the predictive window

In this section, I walk through the process of pricing El Niño/La Niña derivatives/insurance outside the predictive window. That window, before which predictions of El Niño/La Niña for the upcoming year are little better than long term averages, is marked by what climate scientists call the "spring predictive barrier". As recently as 2010, many climate scientists placed that barrier in March. However, it may already have moved into February or January as El Niño/La Niña prediction has steadily improved[6].

[5] *Risk-less* in this context refers to the fact that these arbitrage trades attempt to profit from markets without taking on the price risk associated with the underlying good in the market. They are not free from risk.

[6] In fact, even if February predictions are not valuable, they may still produce herding behavior - with hedgers buying based on the assumption that they are valuable. Indeed, in 2010 a large

Outside the yearly predictive window, SST expectations are relatively straightforward. Traders should generally expect that SSTs in any given month in the future will look like SSTs in the past[7]. When historical averages are the only basis for pricing, options are functionally equivalent to index-based insurance. One of the key theoretical factors that distinguishes insurance from derivatives is the fact that *insurance risk* is limited to situations where neither party has private information relative to the settlement of the contract. By extension, that means that historical averages are the only basis for pricing in insurance. As SST predictions improve over time, insurers will need to push back the sales closing date on their coverage to make certain that they and their clients are making purchasing decisions exclusively based on historical information.

4.6 Modeling the index

I begin pricing with basic exploratory data analysis, graphing the historical record of monthly SST in various ways that might suggest statistical properties of the underlying phenomenon.

Figures 4.6, 4.7, and 4.8 are a histogram, an empirical cumulative distribution function (ECDF), and a kernel density estimate respectively, for absolute SSTs in October[8] from ERSST.3b's Niño 3.4, running from 1950 to the present. In particular, I'm interested to see if these graphs suggest skewness, a bi-modal distribution, or other features that will be important for simulation and modeling in later sections.

The histogram of October SSTs suggests two important characteristics:

- A barrier at roughly 27.5°C - values running up to that level were progressively more frequent while values above that levels were relatively infrequent.

- Two distinct peaks of frequency - the biggest is at roughly 27.5°C and a second smaller peak at roughly 26.3°C.

The ECDF tells a similar story as the histogram. Its S-shape breaks between 27.5°C and 26.3°C. Alone, the ECDF and the histogram might indicate that October SSTs should be fit using a mixture model, combining draws from two distributions.

However, these features are less prominent in the kernel density smoothed estimate in figure 104. The distribution is not clearly asymmetric. While there are two peaks, those peaks are relatively close together and of similar magnitude.

Satisfied by figure 104 that SSTs do not require a mixture model, I chose four parametric distributions to fit to the data: normal, log-normal, gamma, and Weibull.

potential buyer of GlobalAgRisk Extreme El Niño insurance decided against signing a reinsurance agreement after they saw early forecasts of La Niña/neutral conditions in 2010. While it is difficult to know how strongly those early forecasts influenced their decision, it was enough to convince GlobalAgRisk and its reinsurance provider, PartnerRe, to push the sales closing date into January in subsequent seasons.

[7] I discuss non-stationarity in the following section.

[8] According to Dr. Andrew Watkins of the Australian Bureau of Meteorology (ABM), October is the single most decisive month for El Niño/La Niña worldwide. It is consequently the month I use for most of the examples in this chapter.

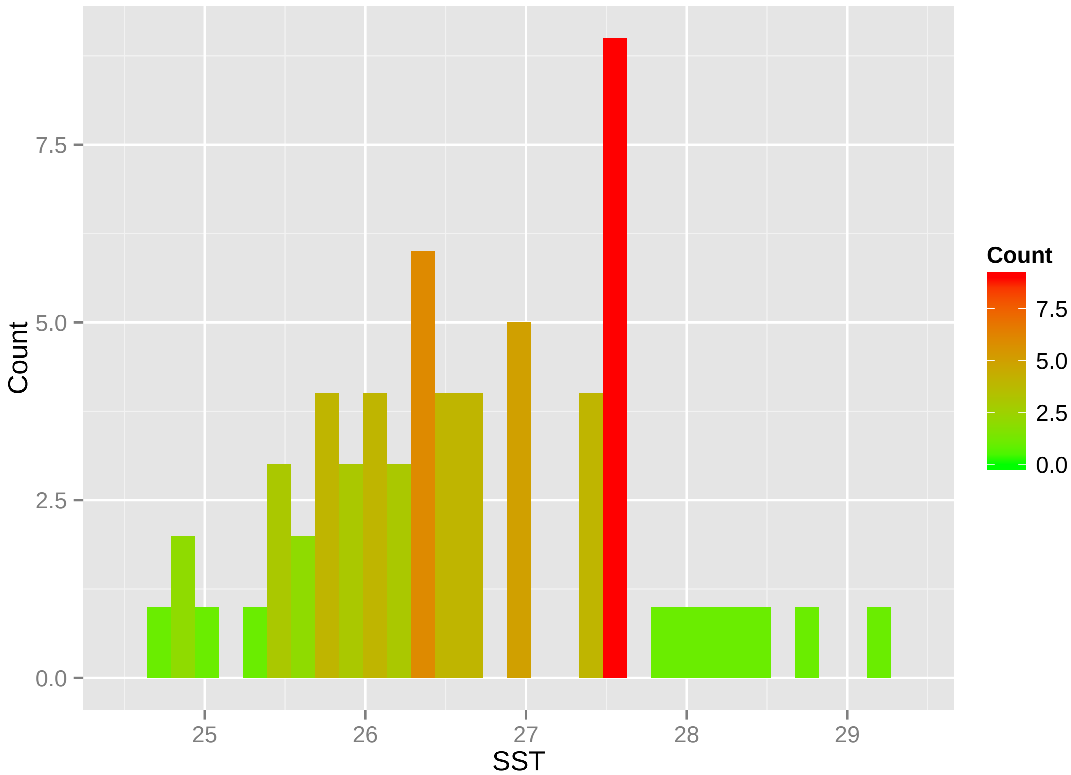


Figure 4.6: Histogram of October SST for Niño 3.4 ERSST.3b

I fit both the normal and log-normal distributions using closed-form minimum least squares routines. I fit the gamma and Weibull distributions using direct optimization of the log-likelihoods (Ripley, 2002). I then generated one million random samples from each of the resulting distributions. QQ plots are shown in figure 4.9. They compare the quantiles of the ECDFs of the randomly generated samples to those from the actual historical SSTs for October.

The Weibull, a member of the family of extreme value distributions, is the only distribution that distinguishes itself in figure 4.9. It shows a poor fit to the data, generating too many extreme draws at both ends of the distribution.

Figure 4.9, suggests that the normal, log-normal, and gamma provide comparable fits to the data. In addition to looking at QQ-plots, I also performed a two-sample Kolmogorov-Smirnov (KS) test on each of the randomly generated samples to indicate whether each generated sample came from the same distribution as the historical record. The KS test uses the null hypothesis that the data from both samples follow the same distribution and we fail to accept the null (suggesting that the samples are indeed from distinct distributions) if the p-value of the KS test falls below our chosen threshold (generally 0.05.) The KS tests were inconclusive, unable to distinguish between the historical record and any of the generated samples at any reasonable level of statistical significance.

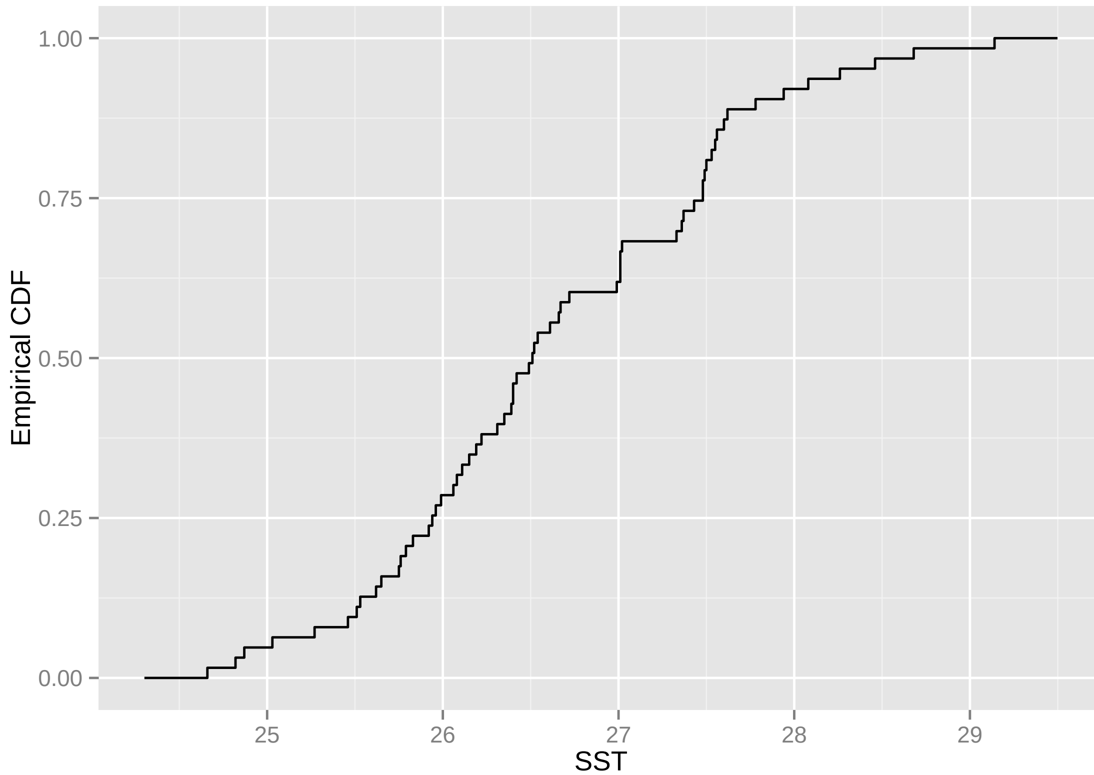


Figure 4.7: ECDF of October SST for Niño 3.4 ERSST.3b

Table 4.1: Kolmogorov-Smirnov test statistics comparing fitted distributional samples to historical SSTs

month	normal	lognormal	gamma	weibull
1	0.57	0.66	0.65	0.33
2	0.77	0.82	0.78	0.18
3	0.96	0.97	0.96	0.36
4	0.81	0.80	0.83	0.76
5	0.90	0.90	0.92	0.70
6	0.91	0.90	0.92	0.82
7	0.96	0.94	0.95	0.62
8	0.97	0.97	0.98	0.58
9	0.77	0.81	0.81	0.47
10	0.80	0.75	0.79	0.37
11	0.53	0.63	0.62	0.18
12	0.75	0.80	0.81	0.36

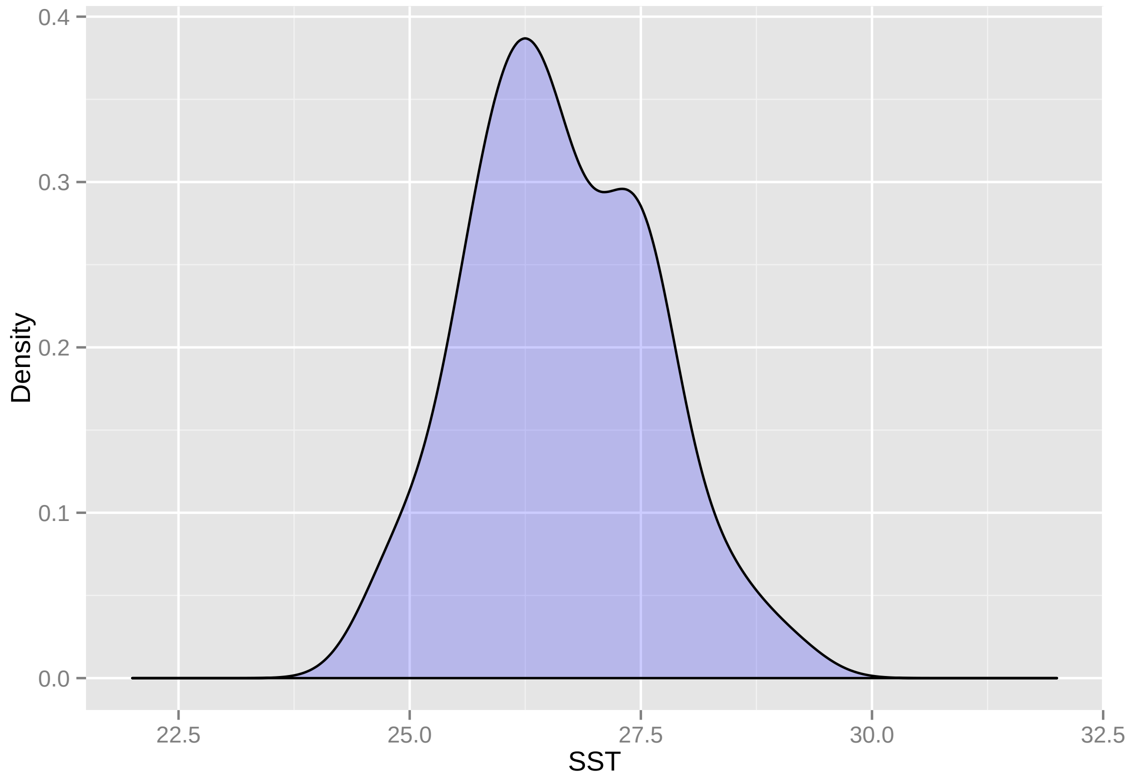


Figure 4.8: Kernel density estimate of October SST for Niño 3.4 ERSST.3b

If ENSO indexes are non-stationary, as implied by figure 3.5, then the parametric modeling in this section must be adjusted to reflect the possibility that Pacific SST anomalies are slowly increasing in strength and/or frequency.

To some extent, NOAA's indexes of SSTs already adjust for that trend, by extrapolating historic measurements using a running window of baseline monthly temperatures. If modelers, believe that the index this adjustment is insufficient, they may attempt to model the index's gradual change directly. Alternatively, insurers who believe that non-stationarity is a real, but difficult to quantify, phenomenon may choose not to model it at all, but to demand a slightly larger risk premium on their insurance.

4.7 Defining a payout function

Prior to pricing, simulated ENSO-SSTs need to be translated into payments for hedgers using a payout function.

I am most concerned with extreme El Niño/La Niña, so I've chosen to structure the payout functions for my example options around events between one and three standard deviations away from the monthly mean. More specifically, payments on the

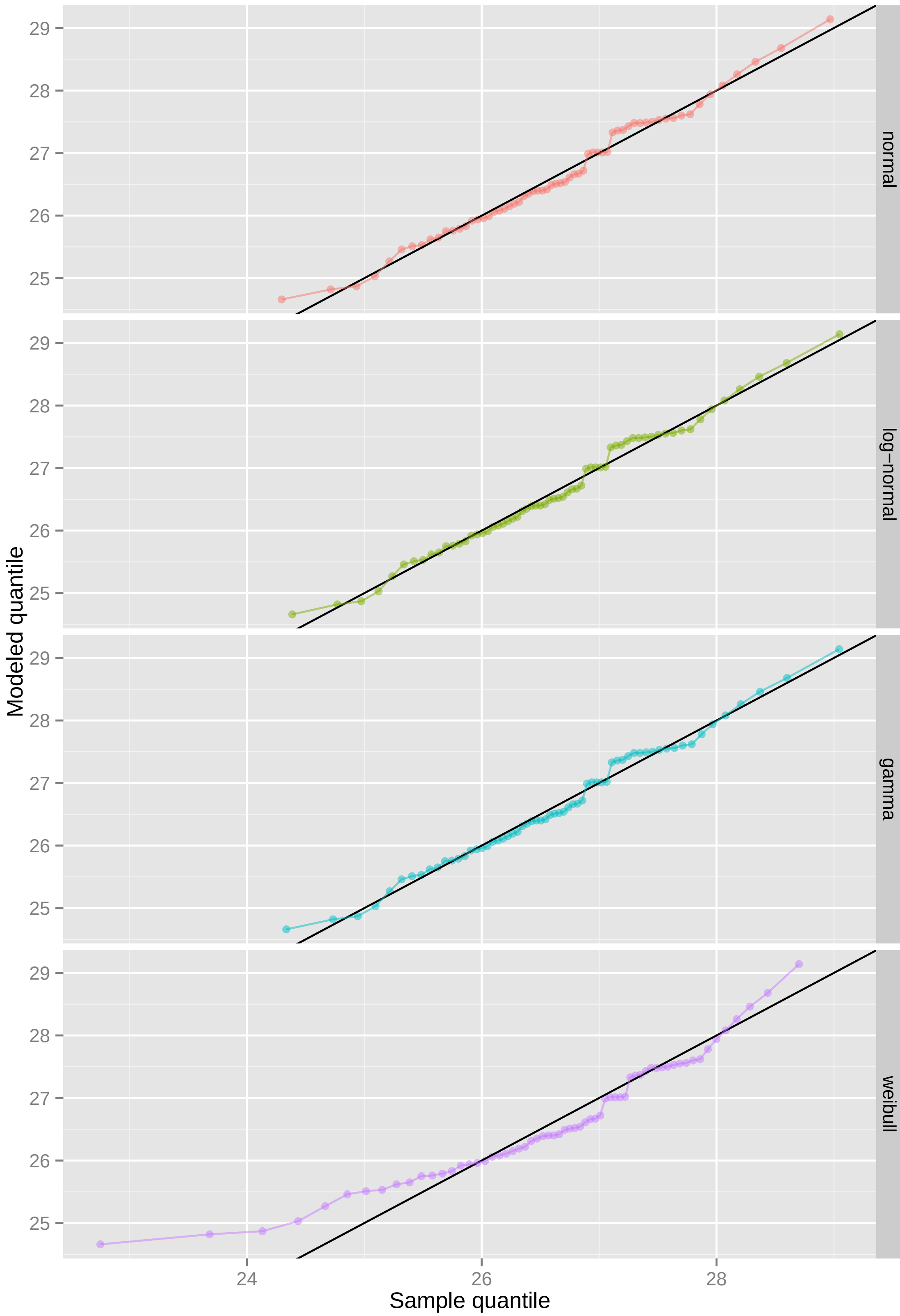


Figure 4.9: QQ plots of October SST for Niño 3.4 ERSST.3b compared to samples from various distributions (n=2 million)

options begin at one standard deviation[9] above or below the monthly average (for El Niño coverage/calls and La Niña coverage/puts respectively) and payments reach one hundred percent of the notional value (or sum insured) at three standard deviations above or below the monthly average. Figure 4.10 shows the average monthly value for Niño 3.4 in black. The red and blue bands show the index values for each month that would trigger a payment on calls and puts respectively.

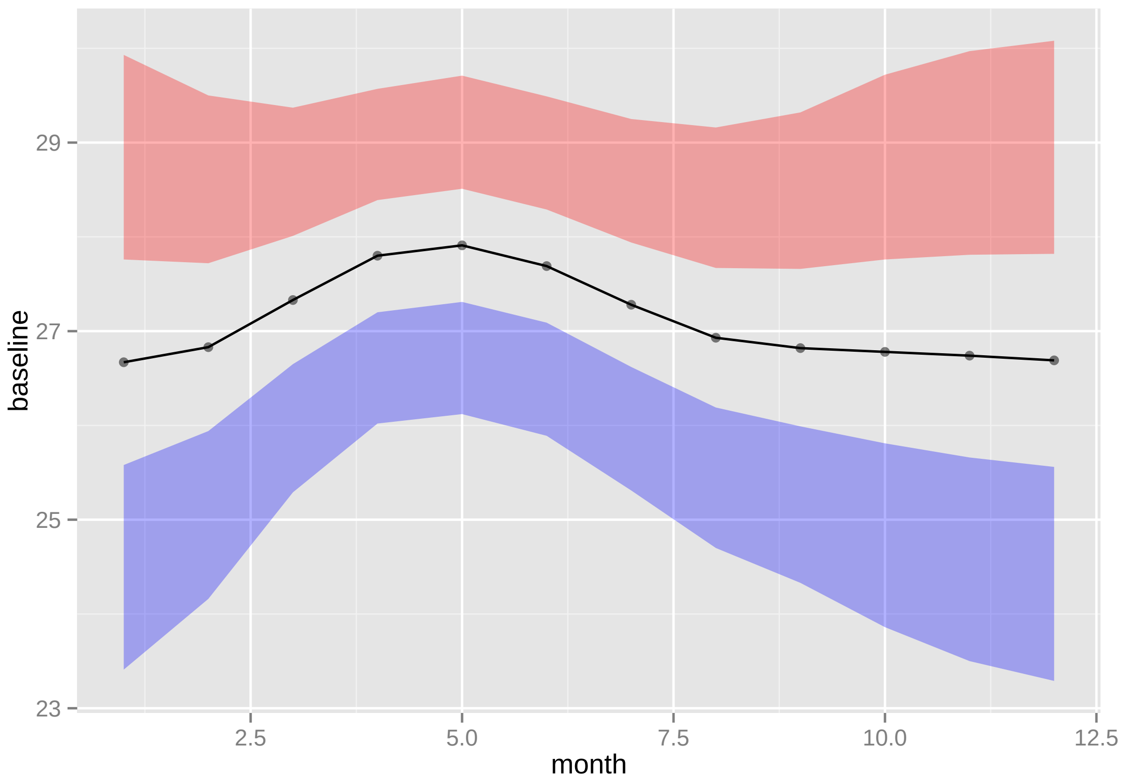


Figure 4.10: Index values for El Niño (red) and La Niña (blue) events between one and three standard deviations away from monthly average

Within those ranges, I use linear pricing such that an index value halfway across the red band in figure 4.10 (i.e. halfway between the the trigger and max payout point) would obligate a payout that is half of the sum insured on a call/El Niño contract. The full linear function for October El Niño is shown in figure 4.11.

As an example, suppose that I bought USD 100 of coverage for USD 10 against October El Niño. If actual October SST was halfway across the red band, or 28.74°C, I would receive USD 50.

In practice, GlobalAgRisk found that hedgers (and speculators) prefer a payout function that offers a minimum payout in the event that the index reaches just above the trigger. For example, an index value that just barely crosses into the red in 4.10

[9]This is also called the trigger or attachment point.

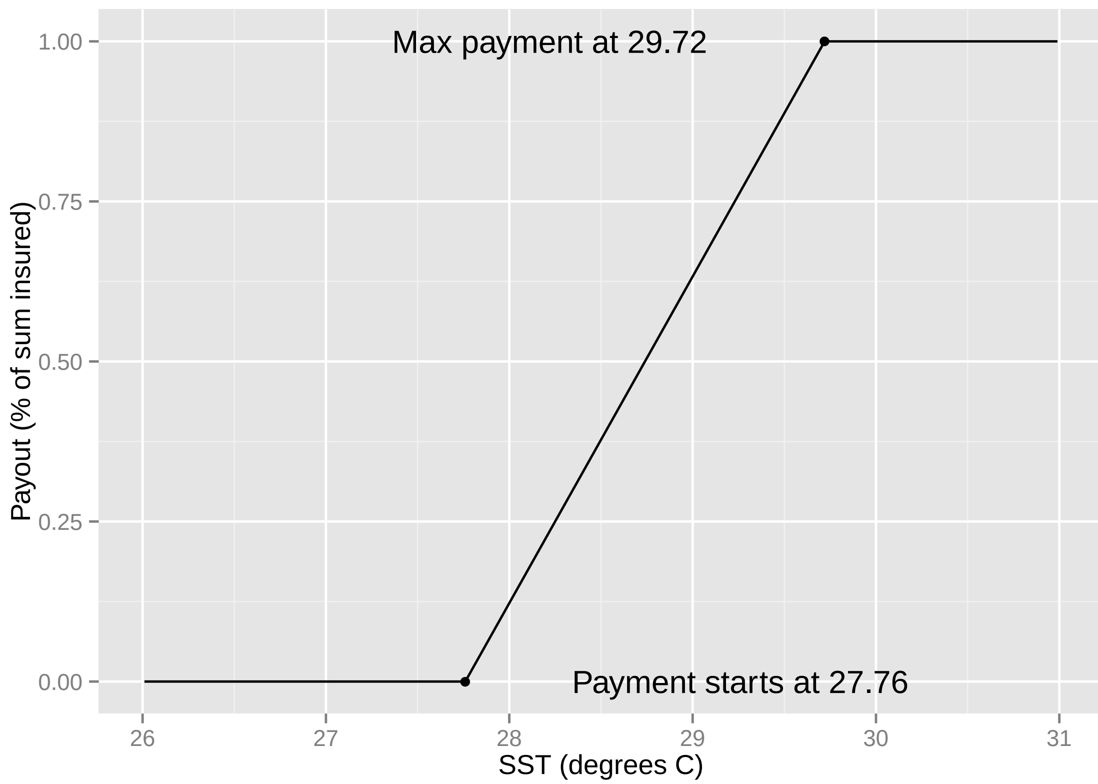


Figure 4.11: Payout function for call option on October SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations above the baseline

might trigger a payout of 5 percent on an El Niño/call contract, rather than the tiny payout suggested the kind of linear function in figure 4.11.

Some potential clients also expressed interest in a more customized payout function consisting of steps usually shaped around historical events e.g. a 25 percent payout for the 1972/1973 magnitude event and a 75 percent for a 1997/1998 magnitude event.

4.8 Static pricing

Given the option parameters, pricing function, and random samples from fit distributions discussed above, I can now price derivatives outside the predictive window.

Initially, I display the payouts generated just by historical October SSTs. The average of these is a starting point for the derivative price. This type of historical pricing is called burn analysis in (re)insurance. Figures 4.12 and 4.13 show burns and average payouts on calls and puts respectively.

As we discussed above, the last 30 years has been very active for El Niño/La Niña events. Earlier decades (going back to the mid-nineteenth century) hosted many fewer

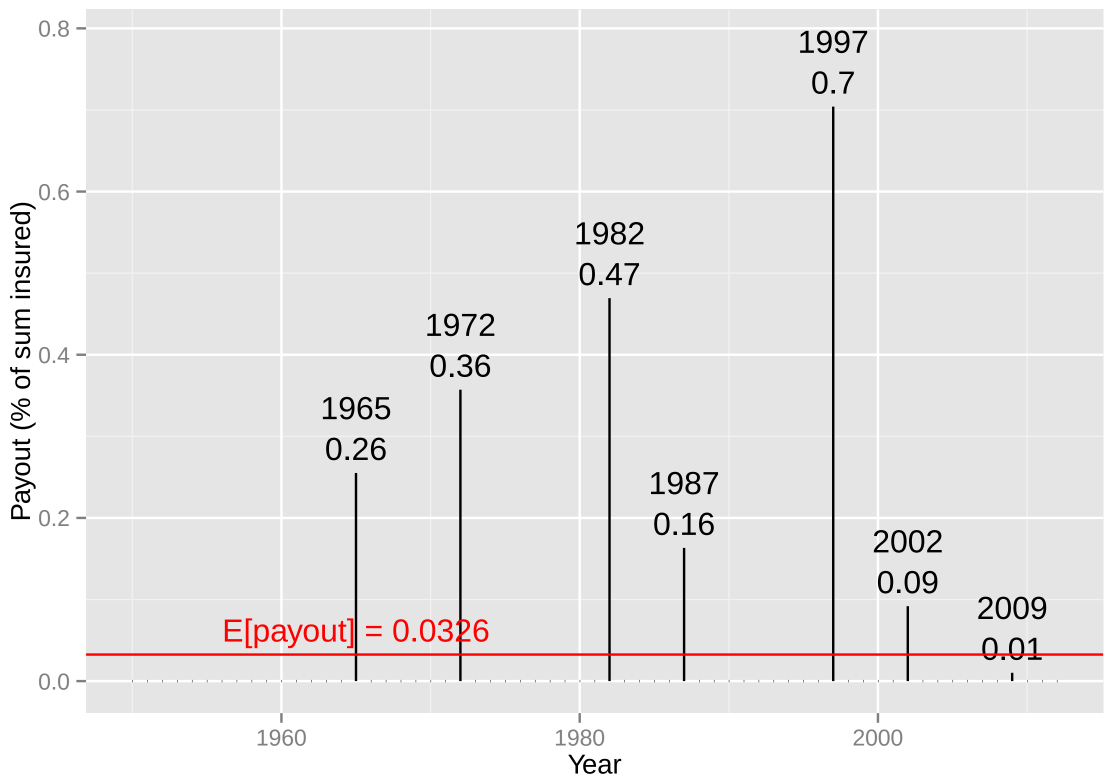


Figure 4.12: Historical burn on call option for October SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

extreme El Niños/La Niñas. Consequently, the burn price displayed here may in fact be high relative to our future expectations for October SSTs.

In figure 4.14, I show the prices generated (in USD of premium per USD 100 of nominal coverage) from the random samples from fit distributions. The figure includes burn prices and prices from samples taken from kernel density smoothers fit over each month.

The prices from the various distributions are, with one prominent exception, close together. On the El Niño side, the highest and lowest prices are mostly within 125 basis points of one another in any given month. On the La Niña side, that spread is slightly larger at roughly 150 basis point, but only between April and June.

The Weibull, is the one model challenging this consensus. The prices from the Weibull samples are clearly distinct from the rest of the group - almost doubling the price of La Niña coverage relative to the rest of the group. The Weibull sample suggested the lowest prices for El Niño coverage, albeit by a much smaller margin than for La Niña. That is understandable given the distribution's heavy left tail.

Apart from the Weibull, the samples drawn from the kernel density smoother suggests the second highest prices for both El Niño and La Niña coverage. The burn prices are in the middle of the pack.

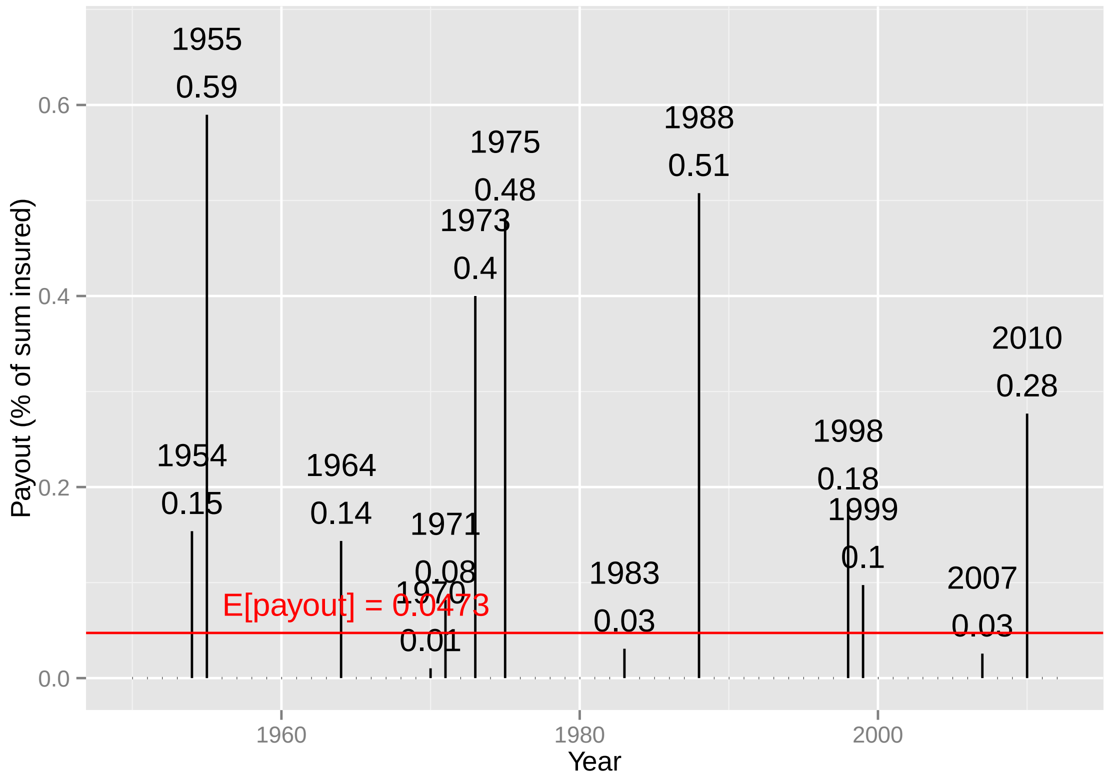


Figure 4.13: Historical burn on put option on October SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

4.9 Pricing inside the predictive window

Extreme El Niño/La Niña events emerge over time, with forecasts giving us even more useful hints in the months leading up to a given event. As those hints emerge, we change our beliefs around the likelihood of an event. The price of El Niño/La Niña risk protection should change to reflect those beliefs.

In this section, I present pricing analysis conditioned on SST forecasts released by Colombia University's International Research Institute for Climate and Society (IRI). Every month since mid-2002, IRI has collected forecasts issued by major centers of climatological research. Figure 4.15 shows IRI the forecasts as of March 2013.

I link forecasts and observed SSTs through a Bayesian regression that uses the long terms climate record as a prior. If the regression indicates that the forecasts have no predictive power, then all the simulated SSTs from the regression will simply reflect monthly historical averages.

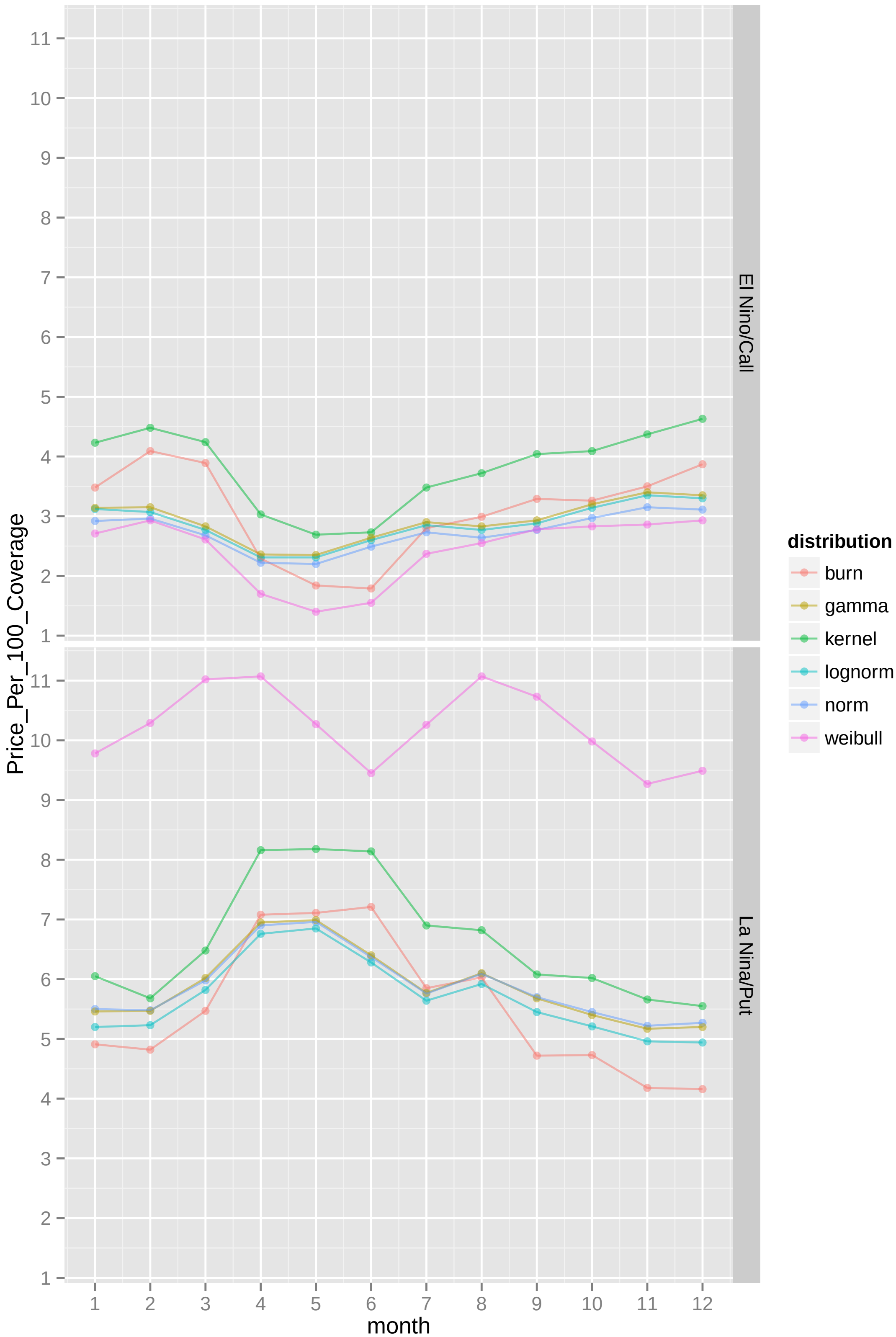


Figure 4.14: Expected price for options on Niño 3.4 by month, based on simulations from various distributions

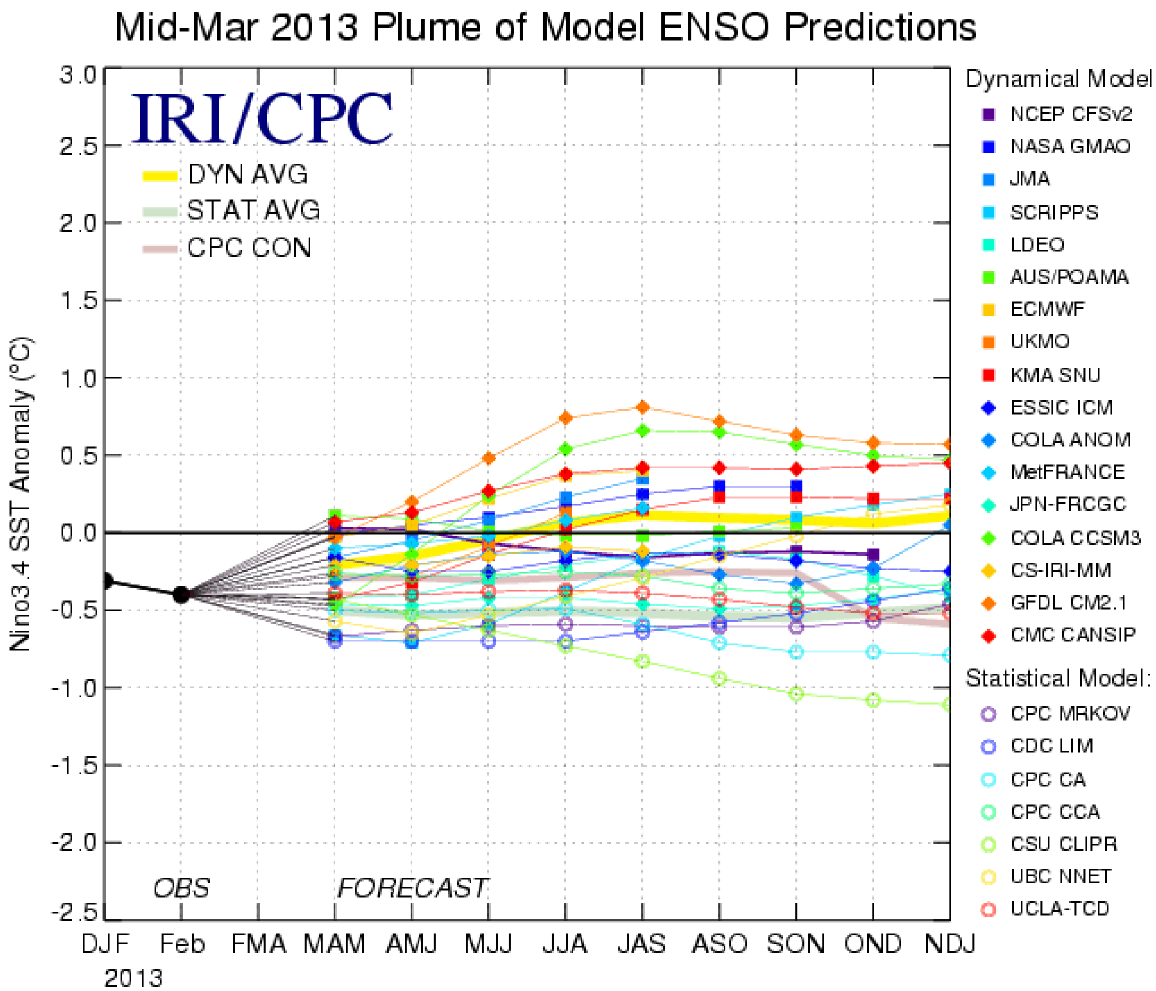


Figure 4.15: Example of IRI's collected forecasts - March 2013

Modeling the link between forecasts and SSTs

As an example, imagine that it is March and I am interested in predicting October Niño 3.4 SST. IRI's forecasts (given in terms of anomalies) are smoothed using three-month blocks, as in figure 4.15. In that figure, there are three forecasts that contain information relevant to October SSTs - *ASO*, *SON*, and *OND*.

There are myriad ways of combining both individual and average forecasts for those three windows in a regression, but in this section I use as my predictive variable the IRI model average. So, in the above example, I would look at all the model averages made in March for *ASO*, *SON*, and *OND*, taking the average of those three numbers in any given year. I did the same for every month across that months valuable forecasts. That forecast average then conditions the long-term average anomaly for October[10]. IRI issues forecasts between 2 and 10 months prior to any given target month. For example, October SST forecasts begin in December and end in September.

[10] I used anomalies rather than absolute SSTs to match IRI's convention.

Since I want pricing for every month, from the vantage-point of every preceding month with IRI forecasts, I need to run a total of 108 separate regressions.

$$\begin{aligned}
\text{Monthly Niño 3.4 ERSST.3b anomalies}_{month,year} &\sim \mathcal{N}(\hat{y}_{month,forecastmonth,year}, \sigma^2_{y_{month,forecastmonth}}) \\
\hat{y}_{month,forecastmonth,year} &= a_{month,forecastmonth} \\
&\quad + b_{month,forecastmonth} * \\
&\quad \text{average of IRI average forecasts}_{month,forecastm}
\end{aligned} \tag{4.1}$$

Those regressions, specified in equation 4.1, are a simplified version of a procedure that climate scientists and statisticians have recently used to merge ENSO forecasts (Luo, Wood, and Pan, 2007) (Coelho et al., 2004). Note first that I do not know the predictive power of IRI average forecasts. The parameter $\sigma^2_{y_{month,forecastmonth}}$ accounts for that forecasting uncertainty. It will be large where IRI average forecasts have shown low historical predictive power. Note also that this Bayesian regression will not be biased by non-stationarity. The underlying parameters are not assumed to be stationary, since they are realizations of an unknown distribution.

The prior probabilities I placed on model parameters are shown in equation set 4.2. There are weakly informative priors on b and σ_y, allowing them to move easily across a wide range of possible values in response to the data. a by contrast has a strongly informative prior based on historical data. This means that if b, the parameter indicating the predictive power of IRI's average forecasts, is at or near zero, then the resulting simulations from the posterior distribution will simply reflect long term trends in monthly SSTs.

$$\begin{aligned}
a_{month,forecastmonth} &\sim \mathcal{N}(\text{mean anomalies}_{month}, \text{st dev anomalies}_{month}) \\
b_{month,forecastmonth} &\sim \mathcal{N}(0, 100) \\
\sigma^2_{y_{month,forecastmonth}} &\sim \text{Inv gamma}(0.001, 0.001)
\end{aligned} \tag{4.2}$$

Dynamic pricing based on model results

The table below contains regression results for October SSTs, predicted between the preceding December and August. The regressions were all estimated using parallel Markov Chain Monte Carlo (MCMC) chains, each with 100,000 iterations, 50,000 of which were discarded as a warm-up (Stan Development Team, 2013). The $\hat{R}$ on all parameters below and the pricing appendices (D through O) were 1, indicating convergence on the simulation.

Looking at the 2.5th and 97.5th percentile of the distributions for b, its clear that the forecasts become more valuable predictors as the year goes on. Going from December to August, the 95 percent probability interval for the forecast parameter, b steadily tightens to a range including 1. This suggest that the correlation between forecasts and eventual SSTs increases throughout the predictive window. As the explanatory value of b increases, a decreases. Just as climate scientists suggested, a's 95 percent probability tightening around 0 after March.

Table 4.2: Bayesian regression linking October Niño 3.4 SST anomalies to average of relevant IRI ensemble forecasts

	mean	sd	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q	n_eff	Rhat
August forecast average covering October Niño 3.4 SST anomalies									
α	-0.10	0.10	-0.40	-0.20	-0.10	-0.10	0.10	91045	1
β	1.10	0.20	0.80	1.00	1.10	1.20	1.50	88920	1
σ_y^2	0.10	0.10	0.10	0.10	0.10	0.20	0.40	56829	1
July forecast average covering October Niño 3.4 SST anomalies									
α	-0.10	0.20	-0.50	-0.20	-0.10	0.00	0.20	92218	1
β	1.20	0.30	0.60	1.00	1.20	1.30	1.70	93712	1
σ_y^2	0.30	0.20	0.10	0.20	0.30	0.40	0.90	54297	1
June forecast average covering October Niño 3.4 SST anomalies									
α	-0.10	0.20	-0.40	-0.20	-0.10	0.00	0.30	95908	1
β	1.40	0.30	0.70	1.20	1.40	1.60	2.10	91107	1
σ_y^2	0.30	0.20	0.10	0.20	0.30	0.40	0.90	55596	1
May forecast average covering October Niño 3.4 SST anomalies									
α	-0.10	0.20	-0.50	-0.20	-0.10	0.10	0.40	92919	1
β	1.50	0.60	0.40	1.20	1.50	1.90	2.60	90255	1
σ_y^2	0.50	0.30	0.20	0.30	0.50	0.60	1.40	59205	1
April forecast average covering October Niño 3.4 SST anomalies									
α	-0.10	0.20	-0.50	-0.30	-0.10	0.00	0.30	88326	1
β	1.90	0.60	0.70	1.50	1.90	2.30	3.00	83902	1
σ_y^2	0.40	0.30	0.20	0.30	0.40	0.50	1.10	57674	1
March forecast average covering October Niño 3.4 SST anomalies									
α	0.00	0.20	-0.50	-0.10	0.00	0.20	0.50	101040	1
β	1.80	0.90	0.00	1.20	1.80	2.30	3.50	96782	1
σ_y^2	0.70	0.50	0.30	0.50	0.60	0.90	1.90	59539	1
February forecast average covering October Niño 3.4 SST anomalies									
α	-0.10	0.30	-0.70	-0.30	-0.10	0.10	0.60	98192	1
β	0.80	1.30	-1.80	0.00	0.80	1.60	3.40	88684	1
σ_y^2	1.10	0.80	0.40	0.60	0.90	1.30	3.20	54912	1
January forecast average covering October Niño 3.4 SST anomalies									
α	0.00	0.30	-0.60	-0.20	0.00	0.20	0.60	99518	1
β	1.00	1.60	-2.30	0.00	1.00	2.00	4.20	92225	1
σ_y^2	1.00	0.70	0.40	0.60	0.80	1.20	2.80	55715	1
December forecast average covering October Niño 3.4 SST anomalies									
α	0.00	0.30	-0.60	-0.20	0.00	0.30	0.70	80946	1
β	-0.30	1.90	-4.00	-1.40	-0.30	0.90	3.50	76663	1
σ_y^2	1.10	0.70	0.40	0.60	0.90	1.30	2.90	56323	1

Using the posterior draws of parameter values from these 108 regressions, I simulated SSTs predicted by each possible forecast value between -2 and 2 (forecasts are rounded to one decimal). For example, I took 50,000 posterior draws of a, b, and σ_y^2 from the regression corresponding to October SSTs predicted by April forecasts. I used each of those 50,000 vectors of three parameters to randomly generate one October SSTs, based on an average April forecast of mild El Niño conditions in the coming October (a forecast value of 0.5.) That left me with 50,000 October SST conditioned on a forecast of 0.5 made in April. I repeated that procedure to produce conditional distributions for SSTs for each month of the year, predicted by a wide range of forecast values, from all possible forecast months. The resulting stochastic catalog allowed me to price El Niño/La Niña risk for any month given any IRI average forecast.

The empirical distribution functions of those posterior simulations, converted back into absolute SSTs, are shown in figures 4.16 and 4.16. In those figures, deeper blue lines indicate colder forecast averages from IRI and deeper red lines indicate warmer forecasts.

Notice how the blue and red lines are tightly bound ten months prior to any given target month (down the rightmost column) in figures 4.16 and 4.17. This indicates that forecasts had little or no predictive power, as warm forecasts were as closely associated with eventual warm conditions as cold forecasts, and visa versa. In some cases, where the blue lines peek above the red, the colder forecasts are actually associated with higher eventual SSTs. The fact that the red and blue lines bunch together as you move left to right across rows in figures 4.16 and 4.17 suggests that the signal from IRI's average forecasts deteriorates as we go further back in the predictive window.

By contrast, two months away from a target month (down the leftmost column of figures 4.16 and 4.17), forecasts are meaningful. Blue lines sit below red lines. So a warm forecast shifts the distribution of eventual SSTs warmer and visa versa.

The spring predictive barrier is also clear in the figures. The difference between April outcomes, conditioned on particularly cold and warm forecasts made just two months prior, is smaller than the same difference for February SSTs made ten months out. In visual terms, the ECDFs for row April, column t-2 months are more compact than the ECDFs for row February, column t-10 months. In other words, April SSTs show a weaker link to February predictions than February SSTs show to predictions from the preceding April.

In table 4.3, I translated these simulation results into pricing for October La Niña protection (put options on October SST). As before in this chapter, I used a payout function that began one standard deviation below normal and reached 100 percent of the nominal value of the agreement (sum insured) at three standard deviations below normal. The full conditional pricing tables for all months, covering both El Niño and La Niña, are available in the ENSO pricing appendices (D through O).

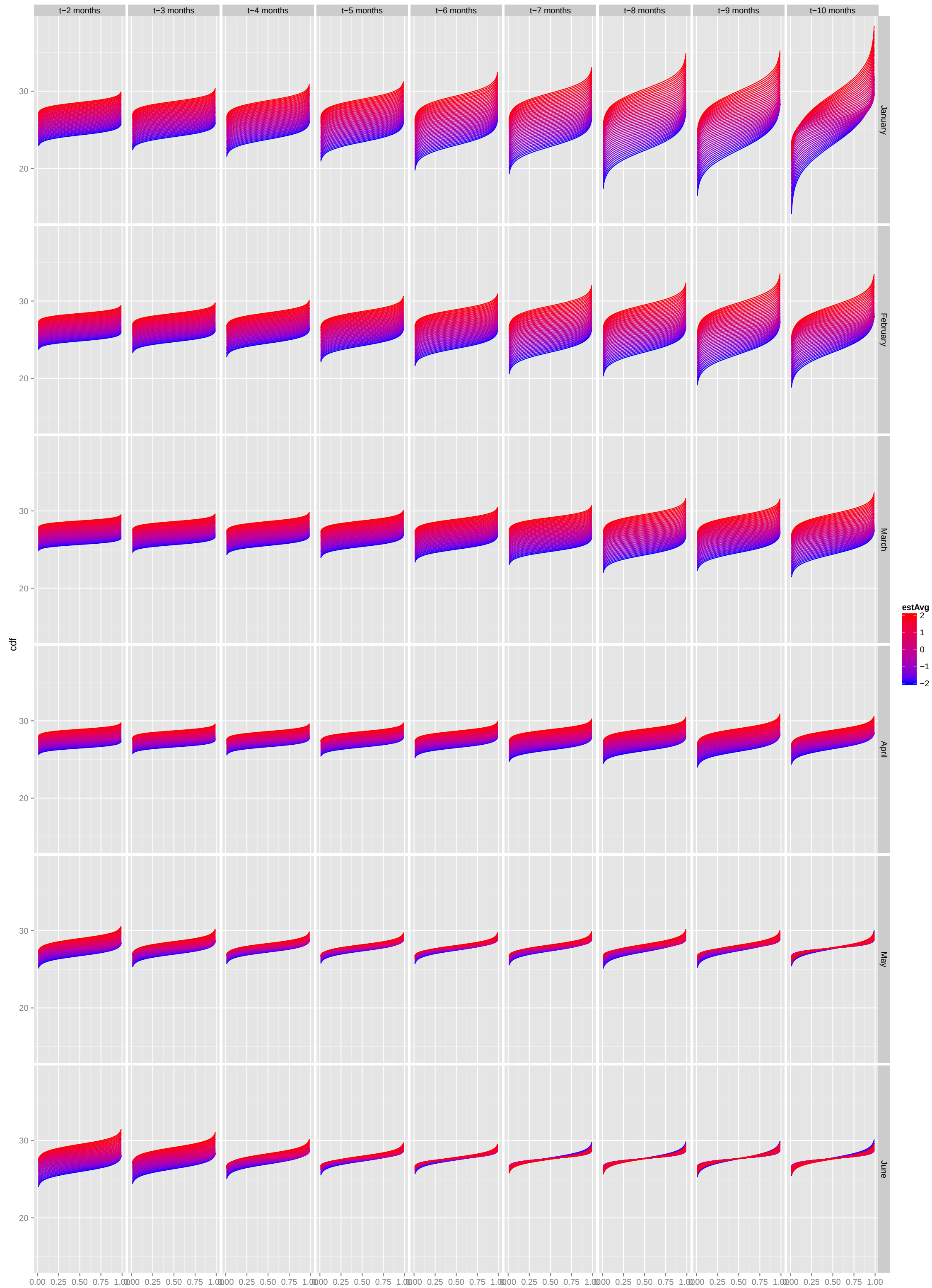


Figure 4.16: Cumulative distribution functions for realized January through June Niño 3.4 SST conditioned on average IRI ensemble forecasts for various months

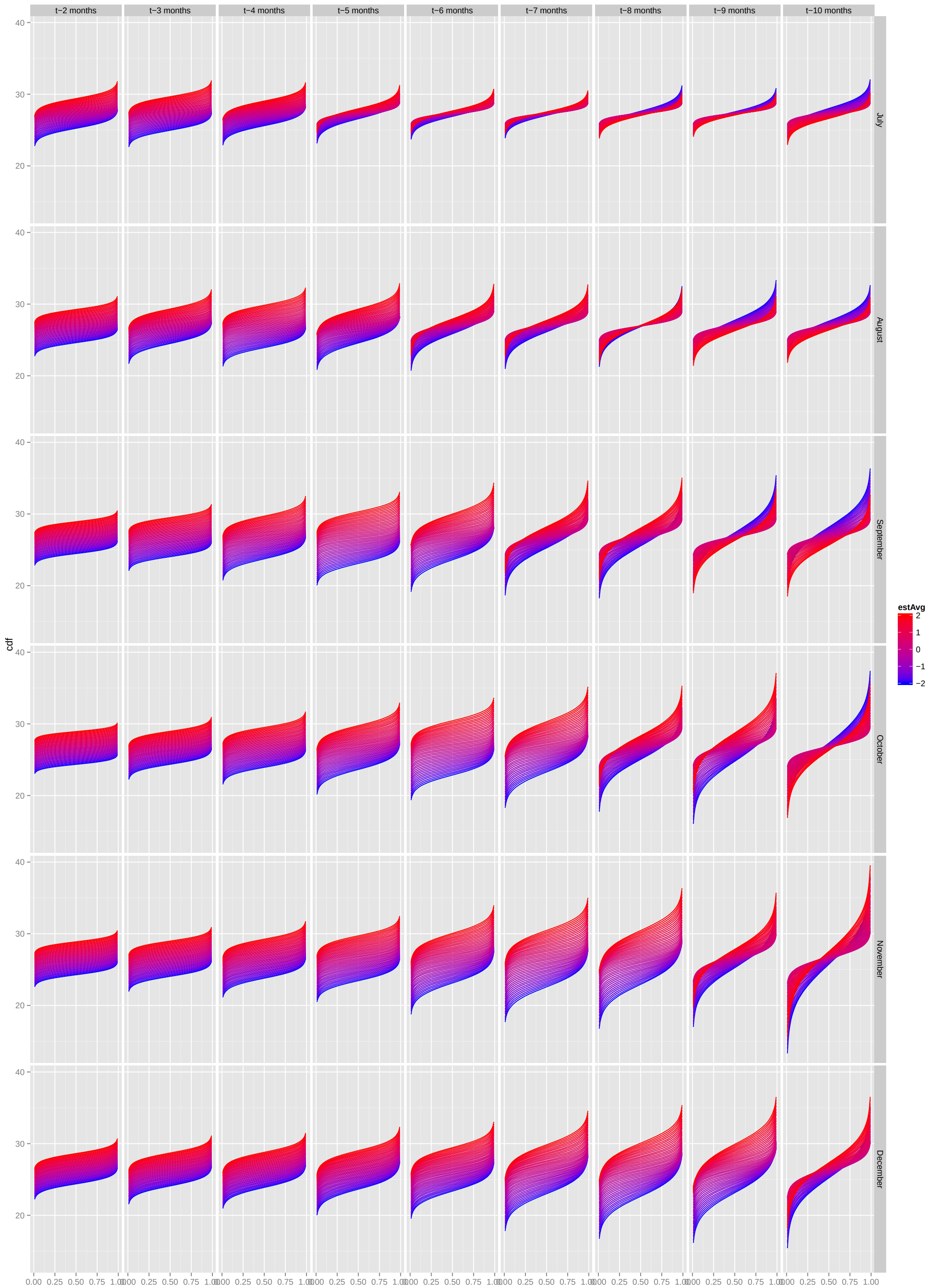


Figure 4.17: Cumulative distribution functions for realized July through December Niño 3.4 SST conditioned on average IRI ensemble forecasts for various months

Table 4.3: Put option prices for October Nino 3.4 SST conditioned on IRI ensemble forecasts released in June

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.80	23.93	0.00	0.66	0.96	1.00	1.00
-1.90	0.77	24.07	0.00	0.59	0.89	1.00	1.00
-1.80	0.73	24.21	0.00	0.54	0.82	1.00	1.00
-1.70	0.68	24.35	0.00	0.47	0.75	1.00	1.00
-1.60	0.64	24.49	0.00	0.41	0.68	0.95	1.00
-1.50	0.58	24.63	0.00	0.34	0.60	0.87	1.00
-1.40	0.53	24.77	0.00	0.28	0.54	0.79	1.00
-1.30	0.47	24.91	0.00	0.21	0.47	0.71	1.00
-1.20	0.41	25.05	0.00	0.15	0.39	0.63	1.00
-1.10	0.35	25.19	0.00	0.08	0.32	0.55	1.00
-1.00	0.30	25.33	0.00	0.02	0.25	0.48	0.99
-0.90	0.24	25.47	0.00	0.00	0.18	0.40	0.90
-0.80	0.19	25.60	0.00	0.00	0.11	0.33	0.81
-0.70	0.15	25.74	0.00	0.00	0.03	0.25	0.72
-0.60	0.11	25.88	0.00	0.00	0.00	0.17	0.63
-0.50	0.08	26.02	0.00	0.00	0.00	0.10	0.55
-0.40	0.06	26.16	0.00	0.00	0.00	0.02	0.46
-0.30	0.04	26.30	0.00	0.00	0.00	0.00	0.38
-0.20	0.02	26.44	0.00	0.00	0.00	0.00	0.31
-0.10	0.02	26.58	0.00	0.00	0.00	0.00	0.23
0.00	0.01	26.72	0.00	0.00	0.00	0.00	0.16
0.10	0.01	26.86	0.00	0.00	0.00	0.00	0.08
0.20	0.00	26.99	0.00	0.00	0.00	0.00	0.01
0.30	0.00	27.14	0.00	0.00	0.00	0.00	0.00
0.40	0.00	27.27	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.41	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.55	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.69	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.83	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.97	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.11	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.24	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.38	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.53	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.67	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.80	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.95	0.00	0.00	0.00	0.00	0.00
1.70	0.00	29.08	0.00	0.00	0.00	0.00	0.00
1.80	0.00	29.23	0.00	0.00	0.00	0.00	0.00
1.90	0.00	29.36	0.00	0.00	0.00	0.00	0.00
2.00	0.00	29.51	0.00	0.00	0.00	0.00	0.00

4.10 Adjusting risk prices for real transactions

The prices in table 4.3 and part 11.4 only reflect the underlying risk of the index. In actual transactions, these pure risk prices will generally be:

- adjusted (downward) to reflect the time value of the premium paid by hedgers;
- subjected to some margining[11] rules, when applicable; and
- adjusted (upward) to allow for some reasonable expected profit for speculators.

I won't address the first two procedures here. Time discounting is straight-forward and I have no expertise in margining. However, I will close this pricing chapter with a discussion on anchoring expectations about speculators' profits.

That anchoring is difficult because there are many reasonable benchmarks for profit expectations. Should speculators expect reinsurance-like returns? Futures-like returns? What have those returns been historically?

Figure 4.18 (discussed in greater detail in chapter 7) shows one reinsurance broker's estimates of returns to investment in CAT bonds and other insurance-linked securities (ILS). ILS markets show returns between 8 and 12 percent above LIBOR over the last decade for wind-exposed risk and between 3 and 9 percent for non-wind exposed risk. Most of the high prices on non-wind risk are clustered at the beginning of the observed period, so margins are at the low-end of that range.

These ILS returns are an important benchmark in their own right, since ENSO risk may trade in the form of CAT bonds. However, these returns are also as a standard proxy for returns in actual reinsurance markets.

Futures markets for major commodities provide another possible benchmark for ENSO risk. Gorton and Rouwenhorst (2004) compiled risk premium estimates for major commodities since 1959 by looking at futures prices relative to settlement at regular intervals. Those statistics are reproduced in the Appendix C: Miscellaneous's table 2. They include the average annualized arithmetic and geometric average returns. Note that these returns are not adjusted above a benchmark like LIBOR, so they are not directly comparable to the estimates in figure 4.18.

One interpretation of table 2 is that some futures markets offer speculators similar risk premiums as reinsurance markets, often above 10 percent per annum. That is surprising, given the general perception that futures are highly efficient.

However, the table also shows that some of the most liquid markets like corn, offer risk premiums of only a few percent. So clearly, the world of futures includes some highly efficient markets that sit along side many others that have provided speculators with high returns over the past five decades.

Regardless of their expected value, the risk premiums in futures markets are evidently more volatile than those in reinsurance markets. None of the markets above show returns that are more than two standard deviations away from zero. That

[11] Margining refers to the process of setting aside collateral on financial trades. On exchange-traded derivatives there are clear, predictable rules for how much money must be set aside as collateral in a *margin account* as the trade's settlement index changes over time.

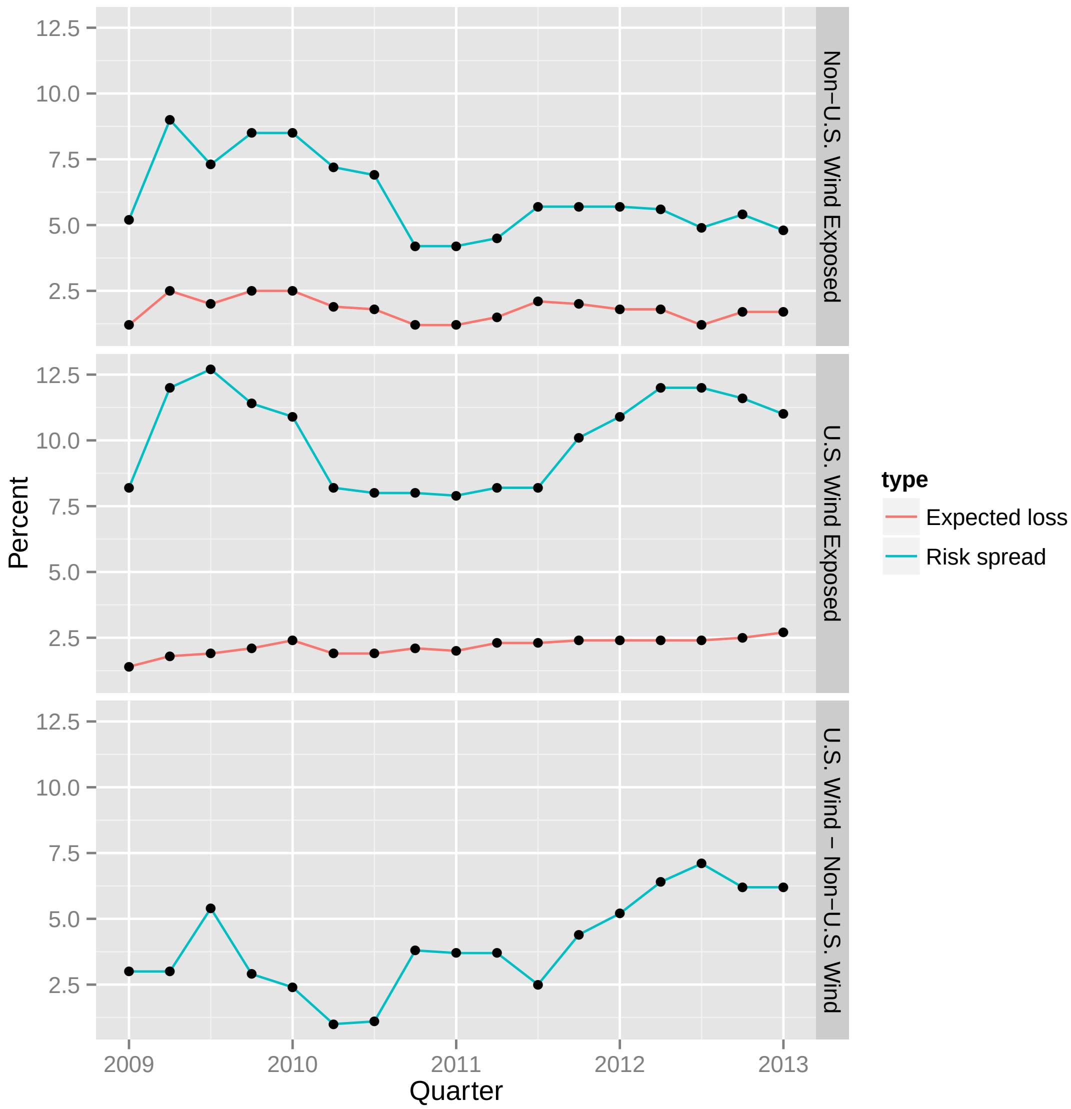


Figure 4.18: Weighted average risk premium and expected loss over last 12 Months on catastrophe bonds from "ILS Market Update" by Willis Capital Markets & Advisory (a large brokerage)

may lead some to dismiss the observation of persistent positive risk premiums as a statistical anomaly.

Are there benchmarks within the world of exchange-traded derivatives that are more directly relevant to ENSO risk than the commodities markets profiled in Gorton and Rouwenhorst (2004)? Chincarini (2011) estimated risk premiums for on heating degree day (HDD) and cooling degree day (CDD) futures contracts on the Chicago Mercantile Exchange (CME). The results of that study are reprinted in Appendix C: Miscellaneous's tables 3, 4, 5, and 6. Only a small percentage of overall weather derivatives trading is in the form of on-exchange futures, so those estimates may not represent weather derivatives as a whole. Nevertheless, they suggest that recent speculative premiums for temperature risk have been on the low end of the range suggested by Gorton and Rouwenhorst (2004). The high volatility of those historical premiums make it difficult to extrapolate about the long-term efficiency of those markets.

Finally, the CME's hurricane index derivatives the bring the reinsurance/ILS premiums noted in figure 4.18 into the context of exchange-traded derivatives. Surprisingly, the efficiency of hurricane derivatives markets relative to ILS is not obvious. The CME's marketing materials suggest a 9.64 percent risk spread over expected loss on an example hurricane contract. That is roughly 40 basis points below the mean risk spread since 2009. But. the risk spread was below that level in 4 out of 10 quarters since 2009 and averaged 150 basis points below the CME benchmark during those quarters.

Chapter 5

Why Futures and Options?

In this chapter, I turn my focus from ENSO risk to the prospects for sustainable trading of that risk. Indexes of ENSO, and teleconnections more generally, could be traded using various financial instruments including over-the-counter (OTC) swaps, index-based (re)insurance, insurance-linked securities (ILS), or exchange-traded derivatives, such as futures and options.

Each of those candidates could provide roughly comparable risk protection to hedgers. However, some have qualities, like continuous trading or additional transparency in pricing, that match particularly well with teleconnections risk. In this chapter I introduce:

- some of the basic characteristics that I believe teleconnection markets should posses; and
- the hypothesis that the natural home for teleconnection risk (particularly ENSO risk) is on futures and options exchanges.

This chapter describes the market structures associated with a host of financial instruments and ultimately makes a value judgment about which structure will support better social outcomes. In that sense, it resembles ongoing discussions of US financial regulations. As regulators implement the Dodd-Frank reforms, they are looking to existing research to answer questions like, "Do some types of financial contracts encourage unsafe borrowing?" and "Do some market structures promote greater access to transactions at the best available prices?".

So, if you are familiar with these candidate financial instruments and how they might match with the risks I discuss in chapters 3 and 11, then you should feel free to skip this chapter. However, keep in mind that the original research in chapters 6 and 8 is a response to the arguments I make here. After I've developed a case for futures and options here, I try to knock that case down in the following chapters by asking "What is the probability that any futures or options market will succeed?" and "Do market professionals agree that El Niño/La Niña indexes can succeed as exchange-traded derivatives?".

5.1 Desirable market qualities

Our recent financial crisis centered on insurance against housing prices. Clearly, that insurance undermined social outcomes. But it doesn't follow logically that we should all stop buying home insurance.

So what distinguishes a financial contract with questionable (or negative) social value from our home insurance or the corn futures that a farmer uses to protect his livelihood from falling prices? What basic market characteristics will allow ENSO and other teleconnection index products to improve the way we make decisions about climate risk?

It is important to have these goals laid out explicitly because new markets rarely form spontaneously. Much more often they are the result of years of hard work by motivated people like the founder of the Chicago Climate Exchange (CCX), Richard Sandor. Despite his strong belief that markets can promote efficient social outcomes, he insists they are man-made creations (Sandor, 2012):

> I was recently invited to lecture students at a leading American business school. Most of these MBA candidates were surprised to find out that financial futures were not introduced until the 1970s. They believed, as most people did, that these innovations have always existed. This simple example highlights the common misconception that efficient markets materialized spontaneously... [T]he evolution of markets is a multi-year, multi-stage process...

Market pioneers have agency in shaping their creations. So, its important that they have a sense of the market characteristics that foster social value.

In this chapter, I focus on a handful of market ideals that I think ENSO and other teleconnection-indexed financial contracts should promote. Those include:

- **Public pricing information** - A market for teleconnection risk should generate prices that provide the public with implicit forecasts of disasters. To the extent that a teleconnection risk is influenced by global climate change, its markets should provide us with dollar-backed[1] forecasts of that phenomenon as well. While all of the candidate market types would generate this information, only some would share it publicly as a matter of course.

- **Dynamic pricing** - Some market types allow hedgers and speculators to enter into trades at any time. In dynamically priced markets, prices change to reflect new information as it becomes available. By contrast, classic insurance markets use static pricing. All trades occur before any special information is available, The price of the trade is based purely off long-term historical data. Neo-classically rational hedgers should not care whether the insurance they are buying is priced statically or dynamically. In reality, this distinction may matter a great deal as hedgers are particularly motivated to enter a trade when they believe a payout is likely - even if the price of the risk protection has adjusted to fully reflect the change in that likelihood.

- **Two-sided pricing** - In some markets, prices are set by one side of the trade (buyers or sellers) and a transaction is only consummated when the other side meets that target price. For example, it is difficult to haggle with Amazon.com about the price of a new kindle book. You either decide the book is worth

[1] ... if indirect...

the price asked or you walk away. In a two-sided market, competing buyers or sellers change the prices at which they would transact and a trade occurs when those *shouts* cross.

- **Modest leverage** - Some degree of leverage (the use of borrowed money to enter into risk transfer agreements) offers risk sellers the opportunity to meet internal profit targets without charging hedgers high risk premiums. Furthermore, it can lower the barriers to entry for new risk sellers, increasing competition. However, leverage may amplify the risk of trade. A market can balance the need for competition (supported by leverage) and the need for stability (compromised by leverage) by enforcing predictable margining rules.

- **Flexible hedges** - Hedgers prefer risk management packages that closely match their specific risk exposures. However, the more specifically a risk package is tailored to the profile of a particular hedger, the less likely it is to appeal to a diverse pool of hedgers. This means that there is often a trade-off between liquidity and basis risk. Some market types attempt to minimize the basis risk of hedgers by allowing customized transactions. Others emphasize liquidity, offering only the most standardized contracts. Ideally, teleconnection markets will strike a balance between those two goals.

In the following sections, I look at each of these characteristics and discuss how different financial instruments promote or undermine them.

5.2 Public pricing information

Forecast fatigue

Why is it so important that ENSO markets provide forecast information? Won't that information be redundant since, as I showed in chapter 4, NMS already provide forecasts of teleconnections anomalies each month?

In the case of ENSO, the information from markets will be valuable precisely because there is so much publicly available forecasting. Hedgers find it difficult to process competing forecasts in the absence of definitive baseline reference points, like the prices from markets. In any given month, some NMS predict looming catastrophe while others tell hedgers not to worry. Figure 5.1 provides a sense of the range of forecasts throughout 2012, a year in which conditions were ultimately normal. In early 2012 some models predicted historically strong El Niño while others suggested a light La Niña.

The climatologists putting together forecasts are comfortable seeing that range of opinions. Indeed, some researchers harness that disagreement among modelers to provide probabilistic forecasts (Coelho et al., 2004) (Luo, Wood, and Pan, 2007). But for an individual Peruvian or Australian, making serious financial decisions based on ENSO forecasts, that disagreement is just confusing.

Not only are forecasts confusing, but they often make it to hedgers only after they've been filtered by media that is understandably more interested in the headline

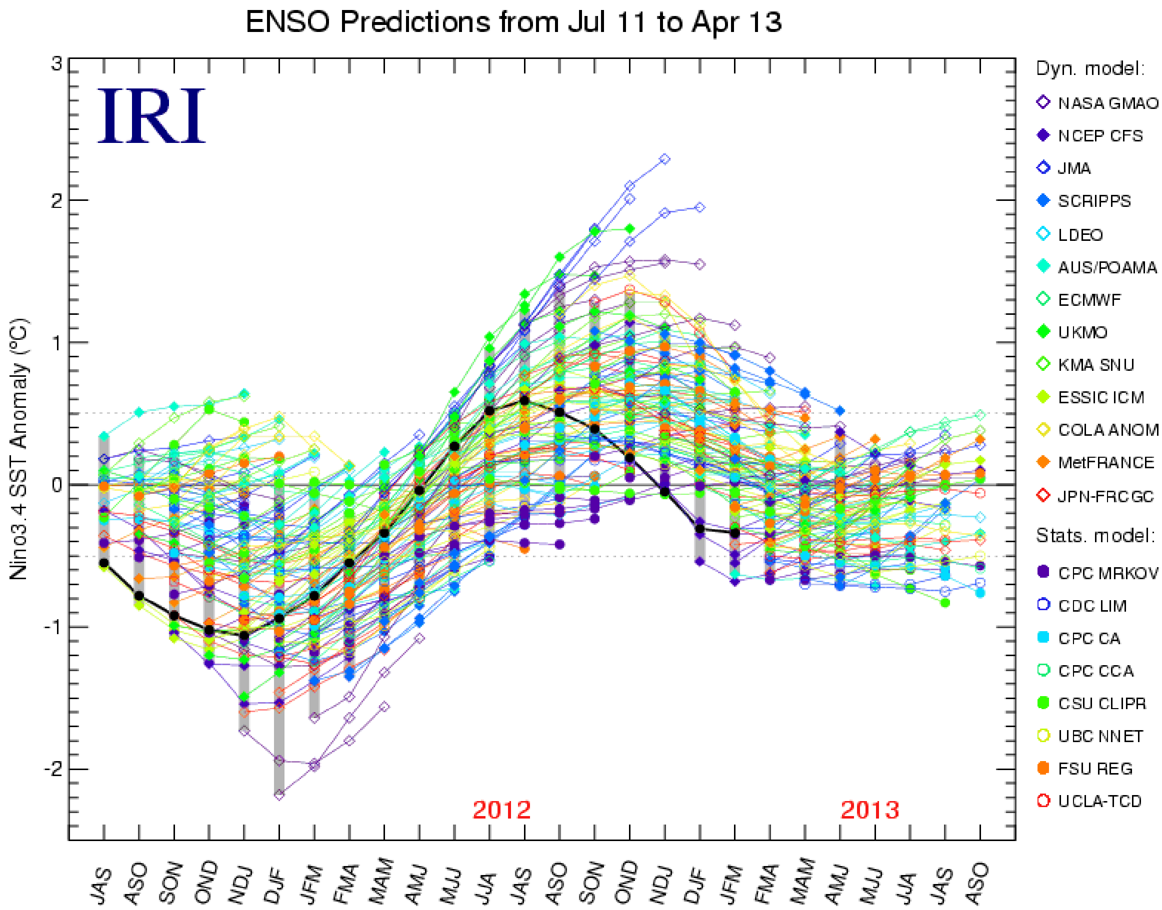


Figure 5.1: Forecasts of ENSO index anomalies between July 2011 and April 2013 compiled by Columbia University's International Research Institute for Climate and Society `http://portal.iri.columbia.edu/`

"El Niño in 2012 according to respected climate group" than its probabilistic cousin, "Climate scientists disagree about 2012 El Niño." Seen through that filter, forecasts would trace the outer edge of the band in figure 5.1, often switching rapidly between La Niña and El Niño.

In the course of my work with hedgers in Peru, forecast fatigue came up often. Extreme forecasts followed by underwhelming events have undermined the trust of Peruvians and left many with mistaken impressions about which years truly saw catastrophic ENSO anomalies. One surprising example came from a large fishing company[2]. A manager told us that his firm would easily withstand an extreme El Niño, as higher prices would offset lower catches. Over the course of the meeting, it gradually became clear that his optimism came from recent experience of moderate events that had been forecast as extreme earlier in the season.[3]

[2]The example is surprising because large fishing companies are, in my experience, particularly adept at valuing probabilistic forecasts.

[3]His belief was not shared by any of the other fisheries we spoke with and certainly at odds with the industry-wide bankruptcy and nationalization that followed the 1982/1983 El Niño.

Unfortunately, the manager's confusion is common in circumstances where individuals are sorting though forecasts as they make risk management decisions. Reading about the response of New Orleans residents to hurricane forecasts in Silver (2012), I found a passage that could as well have described that manager:

> Most New Orleanians had not been alive when the last catastrophic storm, Hurricane Betsy, had hit the city in 1965. And those who had been, by definition, had survived it. "If I survived Hurricane Betsy, I can survive that one, too. We all ride the hurricanes, you know," an elderly resident who stayed in the city later told public officials. (Elder et al., 2007) Responses like these were typical. Studies from Katrina and other storms have found that having survived a hurricane makes one less likely to evacuate the next time one comes. (Gladwin and Peacock, 1997)

Exchange-traded markets as a touchstone for forecasts

Corn farmers face the same problem as El Niño hedgers. There are many forecasts of future prices competing for their attention. Fortunately, they have the option of allowing markets to filter those forecasts.

Some, but not all, markets could provide that pricing information to the public and become the default reference point for ENSO hedgers across the world. An options market would be particularly valuable in this regard. Options prices would provide not just a consensus forecast of the absolute index value, but an intuitive measure of the uncertainty around that forecast. Ideally those option prices would become the default reference for media covering ENSO, just as they have for agricultural commodities.

Exchange-traded markets do an excellent job of providing public pricing information. Exchanges generally use order-book systems, where the lowest outstanding bid (offer to buy at a specified price) and highest ask (offers to sell at a specified price) are displayed to the public. That is meant to ensure that traders always know the price at which they could transact on either side of the market immediately. Market makers are required to always post spreads (pairs of bids and offers) that are good up to a pre-specified order size. By law and convention, exchanges post not only bids and asks, but all consummated transaction prices to central repositories. The information from these repositories is often available to members of the general public for little or no cost. In recent years, those prices have been circulated for free by online brokerages and services like Google Finance.

Block trading and pricing information

There is an increasingly important exception to the general rule that exchange-traded markets provide the highest quality public pricing information: block trades. These are bilaterally negotiated trades (with terms often set over the phone) that are reported to an exchange after they have been consummated. A block trade's underlying asset is already traded on the exchange and its counter-party risk is managed like a normal futures or options position.

Traditionally, block trades were favored by large institutional investors worried that their bulk buying or selling would move market prices against them. Through block trades those large investors find counter-parties that provide them a less favorable price than is available on the market. In exchange for accepting that less favorable price, they receive certainty about the average price they will receive for their full transaction.[4]

Block trades provide the public with the same price and size information as order-book trades, but only after the trade has been consummated. Block trading provides less information about the prices of trades that could be consummated at any given moment. For exactly this reason, the CFTC is attempting to craft its Dodd-Frank rules to discourage market participants that benefit from informational asymmetries in OTC markets from herding their transactions over to block trading on exchanges (Commodity Futures Trading Commission Office of Public Affairs, 2013) (Rennison, 2013a).

My interviews of exchanges and hedge funds suggested that block trading currently dominates on-exchange weather and catastrophe transactions. Some key market participants suggested that block trading may also dominate ENSO and teleconnection trading, should those risks list on an exchange. Given that, it is important to recognize that exchange-trading may not offer the clear improvements in price transparency implied by an offer-book.

Bilaterally-traded markets

In uncleared OTC swaps and ILS, a potential hedger needs to contact a recognized broker (generally by phone) simply to get indicative pricing. As Michael Lewis' *The Big Short* details, in extreme circumstances, those indicative prices may bear little resemblance to actual transaction values (Lewis, 2010):

> With no one else buying and selling exactly what [hedge fund manager,] Michael Burry[,] was buying and selling, there was no hard evidence what these things were worth - so they were worth whatever Goldman Sachs and Morgan Stanley said they were worth... [Burry began] asking Wall Street traders if they would be willing to sell him even more credit default swaps at the price they claimed they were worth, knowing that they were not. "Never once has any counterparty been willing to sell me my list at my marks," he wrote in an e-mail. "Eighty to ninety per cent of the names on my list are not even available at any price." A properly functioning market would assimilate new information into the prices of securities; this multi-trillion-dollar market in sub-prime mortgage risk never budged.

Even in the most liquid OTC markets, indicative pricing may be difficult to find. Duffie (2012) summarizes recent research on price dispersion within bilateral markets, much of which has been influential in Dodd-Frank rule-making:

[4]Mallaby (2011) provides an excellent introduction to block trading in it's chapter on hedge fund mogul Paul Tudor Jones.

> In a relatively opaque OTC market, different investors may pay quite different prices for the same asset at essentially the same time. The investors may vary in terms of their relative bargaining power, their access to alternative trading opportunities, the quality of their information both about the fundamentals of the asset and about recent transactions. For example, Green, Hollifield, and Schürhoff (2007) document dramatic variation across investors in the prices paid for the same municipal bond. Massa and Simonov (2003) report dispersion in the prices at which different dealers trade the same Italian government bonds. Ashcraft and Duffie (2007)... [shows]... that the rate at which a pair of banks negotiate a loan of federal funds in the overnight inter-bank market at a given time of day, relative to the average rate negotiated by other pairs of banks at the same time of day, varies according to the relative cash holdings of the two banks at that moment of the day, the degree to which the two banks are active in the inter-bank lending market, and the extent to which the banks have had a prior borrower-lender relationship, among other factors.

So, bilateral markets struggle to provide even institutional investors with the pricing information that is almost definitional in traditional exchange-traded markets. But that problem is compounded by the fact that only institutional financial firms[5] can transact in specialized bilateral markets, such as OTC swaps and ILS. The distinction between retail and institutional investors is drawn both by explicit regulation and through informal segregation (Davis Polk, 2012).

Normal investors, even small hedge funds, do not have working relationships with the brokers that provide indicative prices on specialized OTC markets. Again, Lewis provides an excellent example of this problem, as one of the investment funds he follows, Cornwall Capital, is repeatedly turned away as they try to establish the brokerage relationship they need to bet against the sub-prime mortgage market (Lewis, 2010). Just as the mortgage market is beginning to collapse, days after convincing an investment bank to grant them special permission to trade, Cornwall Capital sees the first prices from actively-traded securities linked to the mortgage market. That pricing information, more reliable than what was available over the telephone from brokers, immediately provided powerful forecast information:

> Five days later, on February 21, [2007,] the market began to trade an index of CDOs called the TABX. For the first time, Charlie Ledley, [one of Cornwall Capital's founders,] and everyone else in the market, was able to see on a screen the price of one of these CDOs. The price confirmed Cornwall's thesis in a way that no amount of conversation with market insiders ever could have. After the first day of trading, the tranche that took losses when the underlying bonds experienced losses of more than 15 percent of the pool - the double-A-rated tranche that Cornwall had bet against - closed at 49.25: It had lost more than half its value.

[5]Such firms are called "eligible contract participants" by US regulators.

The Dodd-Frank financial reforms are intent on reshaping information flows in OTC swaps markets to improve public pricing information. One pillar of Dodd-Frank's derivative-focused Title VII mandates reporting of basic trade information on many bilateral markets to *Swaps Data Repositories*. This change is meant to improve *post-trade* transparency (i.e. transparency on trades that have happened) ensuring that many bilateral markets provide pricing information comparable to exchange-traded markets. However, the Dodd-Frank rules related to *pre-trade transparency* (i.e. transparency on transaction prices and sizes that are currently available, similar to bid/ask spreads in exchange-traded markets) remain in flux.

It seems likely that swaps markets will maintain some of the trading practices that stifle the flow of information. Transactions on many bilateral markets will remain phone-based, even if those phone-based transaction systems are forced to run parallel to electronic transaction systems with order-book-like features. The dealers that benefit from the informational asymmetries highlighted in Duffie (2012) recently won a major regulatory battle regarding pre-trade transparency. They successfully defeated a CFTC rule that would have mandated that traders solicit prices from at least five firms before a trade can be executed. Instead, the threshold will be two firms, eventually increasing to three in the future (Trindle, 2013).

Reinsurance

Reinsurance markets[6] offer the lowest level of post-trade transparency of any of the market types discussed here. There is no central repository collecting recent transaction data and no regulatory mandate to create one. Even if there were such a mandate, policies tend to be highly customized, making price comparison difficult. Post-trade transparency is almost entirely at the discretion of brokers. Those brokers tend to provide indicative price ranges rather than recent transaction prices.

Pre-trade transparency is also lower in reinsurance markets than in even the least transparent OTC swaps markets. Reinsurance is a one-sided market - sellers generally do not buy and buyers generally do not sell. Whereas brokers in OTC markets quote both a price at which they would buy and sell, reinsurers only quote a price at which they would sell coverage. As I'll discuss in chapter 8, many traditional reinsurers are strictly opposed to using their balance sheets in any way except to sell insurance.

Summary of public pricing information

Pre-trade transparency will be critical to establishing trust in a market with an underlying index that may initially appear complicated to first time hedgers without climate expertise. The climate science behind teleconnections is relatively new and many firms facing climate risk related to teleconnections will have limited prior exposure to formal financial risk management.

In theory, teleconnections markets should be safe for such uninformed traders because they would be homogeneous, cash-settled contracts, based on simple indexes,

[6] Note that although ILS involve insurance-like risk, they trade on secondary markets with bilateral-negotiation.

published by trusted third parties. Historical data on their underlying index is freely available. Hence, even relatively uninformed traders will have all the information they need to make prudent risk management decisions using this market, even if they lack advanced climate modeling capabilities.

In practice, hedgers' comfort will be a function of the market structure. For the market to gain the trust of the full complement of firms with climate risk, those hedgers must believe that they are not systematically facing larger spreads than better connected traders. Exchange markets provide that assurance by promoting high levels of price transparency.

For that reason, I believe exchange-traded derivatives are slightly better suited to providing public information about the ENSO cycle than bilaterally-traded or reinsurance markets. In their most basic form, exchange-traded markets price the gold standard for transparency in pricing. Block trading is on the rise and it blurs the line between bilateral markets and exchange-traded markets. But even with substantial block trading, futures and options prices have anchored forecasts of many risky events for decades.

5.3 Dynamic pricing

In chapter 4 I discussed the tension between prediction and insurance. Prediction opens up the possibility of asymmetric information. Insurers are concerned about the adverse selection created by that asymmetric information. Hence, insurers limit the coverage that they sell on phenomena subject to prediction that is more accurate than long-term averages. That is a problem for a phenomenon like ENSO, for which forecasts improve throughout the year. Instead of using static prices based on long-term averages and a hard sales closing date, the price for ENSO coverage should change dynamically with forecasts.

Sales closing

The reinsurance company selling GlobalAgRisk's El Niño coverage set the sales closing date for their coverage ahead of ENSO's predictive window. That meant that hedgers had to finalize their purchase decision roughly one year before the period of coverage.

Sales closing dates are problematic for two reasons. First, there is no guarantee that the insurance company sets the sales closing date correctly. Forecasts of oscillations are steadily improving and there is no certainty that the insurance company will continually set the correct cut-off date for their insurance sales. Second, sales closing dates increase the opportunity cost of buying protection and disregard the psychological tendencies of hedgers to delay their decisions.

In 2010 GlobalAgRisk's reinsurance partner had set their sales closing date in March. That year, they were in late stage negotiations to sell coverage to a fishing conglomerate as the date approached. Interested in consummating a first sale, they agreed to give the firm two extra weeks to make a decision. It is impossible to know exactly why they decided against purchasing coverage that year. However, we do know now that around that time, the conglomerate received analysis from their own in-house climate experts suggesting that a La Niña was increasingly likely in the upcoming year.

That chain of events was enough to convince the reinsurer that they ought to push back the closing date to January for the following sales season.

As climate scientists improve their forecasts of ENSO, that date will continue to move further and further back. One response to improving forecasts is to encourage multi-year contracts. Those are very uncommon in traditional reinsurance markets, where firms are always hoping to take advantage of the price spikes that follow large loss events[7]. Unfortunately, multi-year contracts avoid the arms race between buyers and sellers prediction only by pushing the effective sales closing date out years before the period of coverage.

Having to pay an insurance premium a full year in advance of the period of insurance coverage implies an opportunity cost for any hedger whose business returns exceed the discount factor that their insurer uses for the time value of their premiums. That discount factor will generally be low.

This problem concerned me greatly as I worked on GlobalAgRisk's El Niño insurance. In an unpublished manuscript, I explored the opportunity cost of El Niño insurance for farm households in depth. My simulations suggested that the profits earned by reinvesting premiums in the years before the disaster, either in safe investments or in the households' own activities, often provided risk protection equal to or better than that offered by insurance coverage priced at the market rate. The difference is stark when compounded over many years. So, in some cases, farm households face steep opportunity costs that overwhelm the value of El Niño risk protection (Cavanaugh, 2011). Multi-year contracts will not remedy that problem.

In addition to this rational economic consideration, there are important psychological tendencies that discourage firms from paying premiums well in advance of their periods of coverage. Skees and Cavanaugh (2013) discusses these tendencies in the context of insurance against catastrophic risks in the developing world. They are important enough factors to make or break innovative new insurance projects.

Derivatives and dynamic pricing

I believe it absolutely vital that teleconnection markets their prices as new forecast information becomes available. Without that dynamic pricing, teleconnection markets will handicap their ability to attract new hedgers, insisting on sales closing dates and long-term contracts that simply are not attractive to many potential hedgers.

Derivatives (including OTC derivatives) have a distinct advantage over reinsurance and primary ILS markets in the way that they provide for dynamic pricing. To be sure, adverse selection can create *lemon problems* (Akerlof, 1970) that undermine liquidity in derivatives markets, just as in insurance markets (Copeland and Galai, 1983) (Glosten and Milgrom, 1985) (Kyle, 1985) (Leland, 1992). However, derivatives are clearly capable of pricing teleconnection forecasts in the manner presented in chapter 4.

[7]Note that most ILS have a three year term.

While it is theoretically possible for insurance companies to offer such dynamic pricing, that is not standard practice. Similarly, in ILS markets, risk tends to be priced at the time of the security issuance. There is some dynamic pricing on secondary markets. But the interviews in chapter 8 suggest that prominent ILS traders consider *Live CAT* trading (i.e. trading on the secondary market when forecasts are available) beyond their core competency.

5.4 Two-sided pricing

Teleconnections create winners and losers. Where Peruvians see El Niño anomalies as harbingers of disaster, American insurers see them as an indicator of strong underwriting profits thanks to a decreased likelihood of major Atlantic hurricanes. In chapters 3 and 11, I estimate the size of some of these major offsetting hedging groups for ENSO and the Arctic Oscillation respectively.

The fact that ENSO's impacts are so diverse across time and space suggests that that an ideal teleconnections market would allow hedgers with offsetting risk profiles to trade directly with one another. Similarly, firms with the expertise to forecast ENSO should have the opportunity to enter that market as buyers or sellers, depending on the prevailing price and spread.

Markets where buyers and sellers simultaneously negotiate, including those in most derivatives, are called two-sided. Brokers or market makers offer their clients spreads, pairs of prices at which they could buy or sell.

By contrast, in one-sided markets such as reinsurance and ILS, there is a clear distinction between buyers and sellers. One party (generally the seller in reinsurance) sets the price and the individuals on the other side of the trade (generally the buyers in reinsurance) have the option to take or leave that offer[8]. In reinsurance markets in particular, the divide between buyer and seller is enshrined in regulations and laws that specify the capital reserving requirements for insurance companies and bar non-insurance companies from selling insurance coverage. Indeed, the difficulty of starting new (re)insurance companies is at the heart of the reinsurance pricing cycle (Froot, 1999).

Theoretically, a one-sided market is perfectly appropriate for some types of risks. For example, there is no large group of firms that naturally benefits from an earthquake[9]. So, the market for risk protection is unlikely to be *balanced*, with hedgers happy to take risk on both sides of an earthquake trade. Instead, one side of the market (the side that is short earthquakes - losing money if they do occur) will be provided by reinsurers. Those reinsurers expect to be compensated for taking that risk.

If teleconnections risk were offered only as reinsurance, firms with offsetting risks would only transact through a reinsurance firm, unless one of the offsetting firms was

[8]Such markets certainly have some informal negotiation or *work-up*, where buyers and sellers negotiate up the size of a transaction at an agreed upon price. But the distinction between buyer and seller remains clear.

[9]...ignoring the select few firms directly involved in the clean-up and rebuilding after an earthquake.

willing to become an insurer themselves. Breaking what could be a single transaction into two suggests additional transaction costs (e.g. now there are two agreements that must be reviewed by lawyers) and it also introduces a speculator, who will collect fees from both sides of the trade. If instead the trade were direct, it might simply transfer risk at a close-to-actuarially-fair price and still benefit both sides.

Modest leverage

In a frictionless world, all of the most common methods of managing counter-party risk in a trade should be equivalent (Mello and Reilly, 2012). In reality, those different methods can promote radically different levels of counter-party risk for individual clients, different barriers to entry for new sources of risk capital, and even different prices of risk for hedgers.

At one extreme sit collateralized reinsurance and ILS. In those markets, the full amount needed to pay worst case scenario claims is set aside using a Special Purpose Vehicle (SPV), essentially an insurance company created simply to hold the capital for that ILS deal. That money is supposed to be invested in safe, liquid assets, so that clients are assured that their funds will be available at a moment's notice after an event. In fact, those agreements are not entirely without credit risk because SPVs have managed their collateral through swap agreement with third parties (Kurtov, 2010). Even with that introduction of counter-party risk (through the swap agreements), ILS and similar reinsurance type arrangements offer protection with relatively little counter-party risk compared to other candidate instruments that could be the basis of teleconnection markets.

On the other end of the spectrum, many OTC derivatives contracts are intended to require no collateral posting. Cash does not change hands until those contracts are settled. That is a source of worry for regulators and under Dodd-Frank, many OTC contracts may be subjected to more stringent counter-party risk measures than exchange-traded derivatives (Duffie, 2013) (Litan, 2013).

In between those extremes are normal reinsurance, which requires substantial capital reserving, and exchange-traded derivatives, which uses clear margining rules to adjust the amount of collateral required by each side of a trade as prices change. See Mello and Reilly (2012) for a simple example contrasting margining on exchanges according to standard margin rules with OTC swaps.

To be sure, credit risk is not desirable for the long-term stability of a market. However, the ILS and reinsurance markets' response to counter-party risk is costly in the short-term and tends to increase the barriers to entry for new capacity providers. Only firms with substantial capital can cover the risk of a full loss upfront. Those firms will then calculate their returns as a percentage of the full capital allocation.

For ENSO, I personally favor modest leverage managed through clear margining rules, as on an exchange. To understand the advantages of modest leverage, I've prepared a simple economic model that I believe bears a strong resemblance to current market dynamics.

Assume the following terms:

- Equity - E
- Return on equity (performance) target - T
- Profit target - TE
- Leverage ratio - L
- Assets under management - LE
- Gross interest rate - I
- Expected return as percentage of assets under management - R

To meet their profit target, traders must follow equation 5.1, across their portfolios.

$$RLE - (L-1)EI \geq TE \tag{5.1}$$

If $L = 1$ then the trading firm is not leveraged, and they must go after a portfolio of opportunities where collectively $R \geq T$. In times when there are plenty of lucrative deals available, investors raise their performance target T, making sure that there is never a persistent opportunity to take deals where $R >> T$. This is the case for much of the reinsurance industry. Low levels of liquidity mean that firms simply will not look at offers with low markups over the underlying risk.

When the market has perfect pricing (i.e. pricing that exactly matched the underlying risk), $R = 1$. So, a social planner looking simply to minimize price while keeping the market functioning would set $R = 1 + \epsilon$ where ϵ is a very small value.

As $\epsilon \to 0$, then it is necessary for $L \to +\infty$ to satisfy equation 5.1. Hence, there is a trade off between the short-term goals of the firms providing hedges and the customers buying them that can theoretically be solved using leverage.

Of course, there is a potential downside to leverage. If we imagine R is stochastic, then a single stochastic instance of a low R with infinite leverage cause immense disappointment ($RLE - (L-1)EI \to -\infty$) and equation 5.1 cannot be satisfied.

So there is a balance to be struck between leverage and competitive prices. ILS and reinsurance lie on one extreme of that balance. With little leverage each individual trade must offer returns at or near a firm's profit target. In the 2008 crisis, OTC derivatives markets were revealed to have experimented with the other extreme. Exchange-traded derivatives with meaningful collateral regulations stand in the middle and represent the best short term option for teleconnection markets.

5.5 Flexible hedges

The link between the frequency and severity of natural disasters is generally non-linear. Instead, they tend to follow power law distributions (see Gutenberg and Richter (1965) for earthquakes, Malamud, Morein, and Turcotte (1998) for forest fires, and Malamud, Turcotte, and Barton (1996) and Turcotte and Greene (1993) for floods) that mean that the next El Niño that is bigger than 1997/1998 may cause flooding in northern Peru an order of magnitude larger than anything ever seen before.

(As I showed in chapter 4, the same is not necessarily true for the underlying SST index.)

If indeed ENSO and other teleconnections create power-law distributed risks then simple linear payouts will do a poor job representing the underlying risk profiles of hedgers (which is non-linear). Duffie and Jackson (1989), suggests that hedging interest will concentrate in markets that reflect the risk aversion weighted losses in the portfolios of hedging firms. So, linear payouts are not only problematic insofar as they create basis risk for hedgers, but that basis risk may undermine liquidity, further depressing the value of the hedge.

Among the candidates discussed here, the only risk market type entirely wed to linear payouts is futures. As Sandor (2012) recounts, the CBOT had to discover this limitation on their catastrophe loss futures through trial and error:

> The CBOT catastrophe insurance futures didn't mimic reinsurance. Option call spreads better simulated the reinsurance layers that the insurance industry was accustomed to. Consequently, the exchange redesigned the contracts and began trading options contracts on September 29, 1995, using the Property Claims Services' (PCS) loss estimates....Later on, due to the lack of industry demand, PCS-indexed insurance futures were dropped entirely. Only cash options on PCS industry estimates were offered for trading.

In options markets hedgers are free to combine contrasts with linear payouts above or below specified index values to produce more flexible risk protection. Indeed, the basic payout function used for GlobalAgRisk's El Niño insurance (see chapter 3) is entirely reproducible using options. However, Sandor (2012) suggests that the CBOT's options remained at a disadvantage relative to reinsurance and ILS insofar as they lacked flexibility both for buyers and sellers:

> Cat bonds were considered more attractive than PCS options because of their inherent flexibility. In a cat bond, a reinsurance company can customize its hedge to be indexed on its own losses, as is done in traditional reinsurance, or it can be indexed on PCS. Moreover, they can be structured to resemble a traditional excess-of-loss reinsurance contract or a quota-share contract, whereby investors share proportionately in the gains and losses of the reinsurer. Cat bonds and the SPV structure also provide the issuing insurance company with access to a broader set of investors than PCS options. Some investors, such as pension funds and mutual funds, are restricted from transacting in derivatives such as PCS options, but are allowed to invest in securities, such as bonds or notes. The ability to offer principal-protected tranches of a note increases the investor base even further because there are some investors who can invest only in AAA-rated securities. This larger set of potential investors may be especially important for companies seeking to transfer large amounts of risk to the capital markets.

Sandor (2012) does not mention competitive pressures from OTC derivatives. Setting aside regulatory constraints on buyers and sellers, those contracts would offer the same design flexibility as reinsurance and ILS.

So, reinsurance, ILS, and OTC derivatives would likely offer hedgers of El Niño/La Niña and other teleconnection risks the most flexible protection. Options contracts are a suitable alternative given the relative simplicity of teleconnection indexes. Apart from a small group of specialized firms, futures will be the least attractive financial instrument for hedgers.

5.6 Summary of candidate financial instruments

I believe that a futures market with an overlaying options market, settled based on a futures price, offers the best available combination of public information, dynamic pricing two-sided pricing, and flexible hedges.

The Case-Shiller housing index market, has adopted this configuration, with most of its hedging activity occurring in options markets settled based on the underlying futures price. This market provides an excellent precedent for teleconnections risk management. It is based on a trusted index of a risk that, while fundamental to economic activity, was unmanaged until recently. Both markets look to attract hedgers previously unfamiliar with derivatives trading and do/could provide socially-valuable information in the form of prices.

It is worth noting that the distinction between OTC swaps and exchanges-traded derivative markets is blurring as a result of financial regulatory changes in the wake of the 2008/2009 financial crisis. In particular Title VII of the Dodd-Frank Act, requires OTC swaps trading to take place on an exchange. While the rules governing that transition are still being written and regulatory arbitrage may insulate many OTC swaps markets from this intended transition, it is worth noting that OTC swaps markets will increasingly display some of the characteristics noted here as particular to futures and options markets.

Also, ILS markets show enough secondary trading to provide some public information about dynamic, two-sided pricing. However, as I discuss in chapter 7 trading remains thin and inaccessible to most investors.

So, while there are many viable alternatives, I do believe that the natural home for ENSO risk in particular is on exchange-traded futures and options markets. In the following chapters I test that hypothesis by looking at the probability of success for new contracts on those markets and by talking to catastrophic risk professionals.

Chapter 6

The Lifecycle of Derivatives Contracts

This chapter is co-authored by Michael Penick, Senior Economist at the US Commodity Futures Trading Commission's Office of the Chief Economist, who provided data and feedback throughout. *THIS CHAPTER DOES NOT REFLECT THE OPINIONS OF THE CFTC.*

In chapter 5, I suggested that the natural home for teleconnection risk is on a derivatives exchange. But my reasoning assumed that ENSO markets will reach a sustainable level of liquidity. That assumption begs a follow-up question: what is the probability that ENSO markets will reach a sustainable level of liquidity? Or, more fundamentally: what is the probability that any new market will reach any given level of liquidity?

To that end, this chapter provides:

- a statistical description of the lifecycle of exchange-traded derivatives in the United States.

Using annual volumes for most derivatives reported to US exchanges since 1954, we present distributional estimates of the rate at which derivative trading volumes rise and fall. Our results provide the first published statistics on the full lifecycle of derivatives and illustrate fundamental changes in cleared derivatives markets over the 2000s. In that decade, derivatives with low trading volumes moved to modest volumes with increased probability. Prior to the 2000s, low volume contracts were more likely to remain stuck at low volumes or be delisted altogether. This additional resilience from low levels of trading meant that the expected trading volume for a new cleared derivative after ten years of trading actually grew between the 1990s and 2000s. This is surprising given that many new contracts were launched in the last decade and a historically large percentage of contracts traded at low volume in any year.

We also discuss the relative influence of exchange and product type on volume patterns. We find that trading volumes varied more decade to decade than from exchange to exchange or product type to product type.

The results are presented as a non-stationary Markov model. Each row in the Markov model's transition matrix (the probabilities of a derivative moving from a given state of trading to any other) consists of posterior draws from a Dirichlet process estimated using Bayesian methods in R and JAGS. This approach to the lifecycle of a derivative allowed us to make simple distributional comparisons among subsamples (including significance testing) and facilitated further simulation of new derivatives emerging over time.

6.1 Introduction and Literature Review

Silber (1981) and Carlton (1984) provided some of the first summary statistics on the survival of new futures contracts. Their core conclusions - that most new derivatives fail and that they do so soon after their launch - remain widely cited (Gorton and Rouwenhorst, 2004) (Hung et al., 2011). However, since those articles, technological innovation and organizational changes at derivatives exchanges have altered the economics of derivatives trading in ways that may have also upended long standing patterns in product lifecycles (Gorham and Singh, 2009).

Recently, Gorham and Kundu (2012) used a large dataset from the Futures Industry Association (FIA) to demonstrate a steep increase in the rate at which new futures contracts are launched.They also provide point estimates for multiple metrics for the success of new futures contracts. Here we extend the work in Gorham and Kundu (2012), providing distributional estimates of contracts' movement between states of annual trading volume using a dataset that includes cleared derivatives and options as well as many historical contracts that are absent from most electronic databases.

Derivatives reform and lifecycle statistics

Basic statistics on the lifecycle of derivatives are particularly valuable now because ongoing policy debates on derivatives regulation in the US and Europe have hinged on projections of how new regulations will impact liquidity and trading patterns. Better baseline statistics of the lifecycle of derivatives, particularly statistics that take into account recent shifts in the dynamics of exchange reported derivatives trading, can inform that debate.

Title VII of the Dodd-Frank reforms focuses on swaps markets[1,2], the hitherto unregulated derivatives markets that, since the first publicly disclosed swaps trade in 1981, had grown to a notional outstanding value of USD 639 trillion by June 2012. (By contrast, options and futures had a combined notional outstanding value of USD 60 trillion (Bank of International Settlements, 2012).) Title VII mandates that swaps markets adopt practices related to many critical market functions (such as information dissemination, counter-party risk, and margining) comparable to those of exchange-traded futures and options.

This regulatory change suggests that the coming years will see convergence between previously unregulated swaps markets and standard exchange-traded deriva-

[1]Swaps trades have generally been negotiated bilaterally, often over the phone through or with large *swap dealers*, rather than via the central limit order book system used by exchange-traded derivatives. This distinction, between markets using bilateral negotiation and those using central order books, has important implications for how information spreads among market participants and how counter-party risk is managed.

[2]The distinction between swaps and futures is often murky. For example, some swaps trades are negotiated bilaterally and then converted into futures trades on markets such as the CME Group's ClearPort. Those trades are reported to exchanges and are consequently included in the dataset used in this article. The CME and ICE, the two largest US futures exchanges, have recently announced plans to convert many of their most popular swaps markets into futures markets with physical delivery of swaps contracts at settlement (i.e. futures trades that become swaps), providing yet another hybrid model.

tives markets. This convergence, in turn, raises both normative questions (How desirable is the move toward increased clearing, public disclosure of pricing information, and greater standardization of margins?) and positive questions (What will the likely costs or regulation be in terms of trading volume?) that would benefit from reliable statistical descriptions of the lifecycle of derivatives.

The relative scarcity of basic statistics on the lifecycle of derivatives has already introduced confusion into the policy debate surrounding Title VII. In one prominent example, the International Swaps and Derivatives Association (ISDA) released a position paper on regulations mandating price transparency and clearing in swaps markets comparable to that in exchange-traded derivatives markets in late 2011 (ISDA Research Staff and NERA Economic Consulting, 2011). The paper highlights previous research showing high rates of failure among exchange-traded derivatives. Assuming a connection between those failure rates and exchanges' price transparency and clearing, the paper goes on to argue that swaps contracts subject to proposed regulations would subsequently lose their liquidity and begin to fail. That suggestion is misleading. First, it ignore the comparable failure rates for bilateral swaps, which are difficult to quantify. Second, it relies on the assumption tested here - that derivatives continue to fail at the rates documented decades ago. Our results suggest that assumption is not robust to recent changes in the underlying structure of cleared derivatives markets.

In addition to providing common ground for policy debates, we hope that the following analysis will inform the decisions of derivatives innovators. In general, contracts are showing greater flexibility, moving up from low levels of annual trading. This may have implications for how exchanges allocate their limited budgets for marketing and education. Contracts previously considered too uneven in their year-to-year trading to succeed may indeed have substantial growth potential given proper marketing and educational support.

6.2 Data

Our analysis is based on annual volume figures for US exchange-traded derivatives (primarily futures, options, and cleared swaps). These figures are/were freely available to the public through trade publications, directly from exchanges, in newspapers, and from the website of the Commodity Futures Trading Commission (CFTC). For ease of access, we used:

- An electronic database maintained by the CFTC aggregating basic, market-level daily trade data (such as volume and open interest) regulated futures and options exchanges, called *designated contract markets (DCMs)*, This dataset covers all recent trading volumes reported to US exchanges of futures, options and swaps, cleared pursuant to DCM rules. Most contracts in that database have volume figures dating back to the early 1980s.

- We supplemented this basic dataset by adding in futures trading figures compiled by hand from historical publications released by derivatives exchanges.

The resulting dataset includes many short-lived contracts listed on now-defunct exchanges that are unlikely to appear in most electronic databases of trading statistics.

The merger of these resources may represent the most comprehensive dataset on derivatives trading volume to date.

6.3 Markov model for the lifecycle of derivatives

We present our primary results in the form of a Markov model. That model begins by imagining that a derivative contract moving between discrete states (x) of trading volume at discrete times (t as in x_t)according to a discrete-time Markov chain, defined generally as in equation 6.1.

$$P(X_t = x_t | X_{t-1} = x_{t-1}, X_{t-2} = x_{t-2}, \ldots, X_0 = x_0) = P(X_t = x_t | X_{t-1} = x_{t-1}) \quad (6.1)$$

In the context of derivatives, the left side of equation 6.1 can be restated as in equation 6.2.

$$P(\text{Volume level}_{\text{year t+1}} | \text{Volume level}_{\text{year t}}) \quad (6.2)$$

Contract are assigned a martix (P as in equation 6.3) that describes the probability of moving to any of a set of discrete states (time j) of annual trading volume in the following year given their state of trading volume today (time i). This is the transition matrix commonly used to describe a Markov process (Page, 2012).

$$P = \begin{pmatrix} p_{1,1} & p_{1,2} & \cdots & p_{1,j} & \cdots \\ p_{2,1} & p_{2,2} & \cdots & p_{2,j} & \cdots \\ \vdots & \vdots & \ddots & \vdots & \ddots \\ p_{i,1} & p_{i,2} & \cdots & p_{i,j} & \cdots \\ \vdots & \vdots & \ddots & \vdots & \ddots \end{pmatrix} \quad (6.3)$$

Volume level for any given contract-year is equivalent to the common logarithm of the annual trading, rounded down to the nearest integer. (For example, annual trading of $10,500$ is assigned a volume level that groups it with all contract-years with volume $\geq 10,000$ and $< 100,000$.) We assigned a special level for annual trading of 0.

For ease of estimation we work with the rows of the transition matrix P which we denote as θ. Those rows sum to 1, so, assuming that row entries are randomly distributed, each row can be assigned a Dirichlet distribution, commonly used for the probability of ending in an exhaustive set of categorical states. That assignment is defined in equation 6.4.

$$\begin{gathered} \text{Volume level}_{\text{year t+1}} | \text{Volume level}_{\text{year t}} \sim \text{Categorical}(\theta) \\ \theta \sim \text{Dirichlet}(x_{\text{vol level 0}}, x_{\text{vol level 1}}, \ldots, x_{\text{vol level }10^8}) \end{gathered} \quad (6.4)$$

We modeled these transition probabilities via Bayesian Gibbs sampling through R and the Bayesian statistical package JAGS (Plummer, 2003). (We used the "rjags" package (Plummer, 2013).) These methods treat the underlying probabilities of moving between states of trading volume as randomly distributed parameters, as in equation 6.4.

After estimation, we combine the vectors θ to reconstruct the transition matrix for a Markov model P. As with any Markov model, we can multiply a vector, $\boldsymbol{\pi}_0$ describing the probability that a new derivative will start in any given state (at time 0) by the transition matrix to produce a vector of probabilities that a new market will be in any state over an arbitrary number of periods (k) as in equation 6.5.

$$\boldsymbol{\pi}_0 P^k = \boldsymbol{\pi}_k. \tag{6.5}$$

We can multiply the vector $\boldsymbol{\pi}_k$ by yet another vector of annual trading volumes corresponding to each possible state to get an approximation of the expected trading volume in that arbitrary year. We present all our expected trading volumes at a ten year horizon (setting $k = 10$), but the Markov model is flexible in this regard.

Note that we do not assume that the transition matrix P is stationary across time. For that reason we call our model a non-stationary Markov model. That non-stationarity means the resulting expected value estimates do not describe an equilibrium, only the general direction of the market.

Prior probabilities on moving between states of annual volume

Our model presumes that the data on the volume level next year (Volume $\text{level}_{\text{year t+1}}$) is segregated by the volume this year (Volume $\text{level}_{\text{year t}}$) and we assigned each of those subsets prior probabilities (corresponding to parameter x in equation 6.4) of moving to any volume level in the next year. Those priors came from an informal survey of economists at the CFTC.

That survey found beliefs corresponding roughly to:

- $\Pr(\text{Volume level}_{\text{year t+1}} = \text{Volume level}_{\text{year t}-1}) = 0.16$
- $\Pr(\text{Volume level}_{\text{year t+1}} = \text{Volume level}_{\text{year t}}) = 0.63$
- $\Pr(\text{Volume level}_{\text{year t+1}} = \text{Volume level}_{\text{year t}+1}) = 0.14$

The probability of a contract jumping more than one order of magnitude up or down was assigned a value of 0.01. In edge cases ($\text{Volume level}_{\text{year t}} = 0$ and $\text{Volume level}_{\text{year t}} = 10^8$) where a move up or down would take the contract below annual trading of 0 or to annual trading $\geq 10^9$, we combined the probabilities of moving up or down with the probability of remaining in the same state. Table 1 shows the full matrix of transition probability priors.

We chose to assign informative priors on transition probabilities because flat priors (equal weighting to the probability of a transition to any state) unfairly biased the estimation, giving exchanges or product subgroups with few observations a relatively high probability of jumping to extraordinary levels of trading.

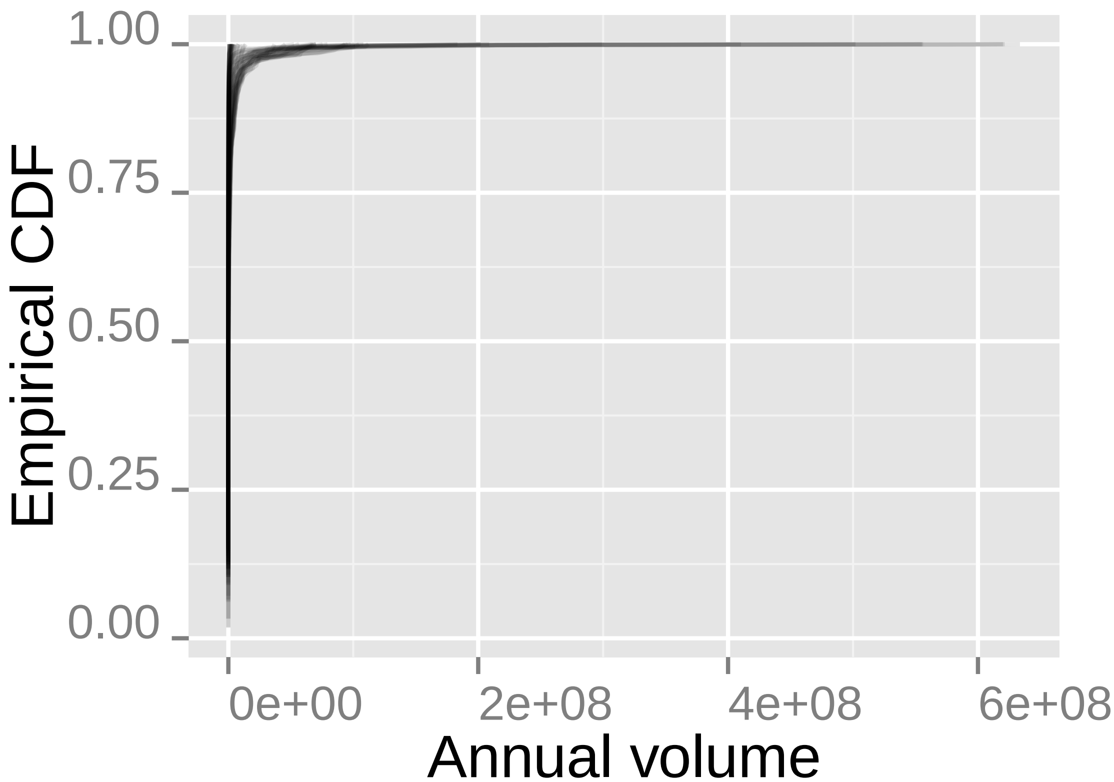


Figure 6.1: Empirical cumulative distribution function of annual trading volumes by contract

6.4 Derivatives volumes over time

Concentration of trading volume over time

Figures 6.1 and 6.2 display the empirical cumulative distribution function (ECDF) of annual trading volumes by contract for every year in the sample. In each figure, individual lines represent the ECDFs for a single year, with lines approaching a right angle showing greater concentration of trading volume in a few contracts. Figure 6.1 clearly shows that most contracts trade at low volumes in any given year, with roughly 80 percent of contracts showing little or no volume in any given year since 1954.

However, figure 6.1 obscures substantial variation in the concentration of volume over time. Figure 6.2 zooms in on the same annual ECDFs displayed in figure 6.1. The ECDF for each year is colored chronologically, with the lines representing the oldest years in the sample in red and the most recent years in purple. Each panel of figure 6.1 shows the same ECDFs, but the years in a specific decade are highlighted (in black) to give a sense of how concentration has varied from decade to decade.

In this graphic we see clear patterns in concentration over time. Markets grew steadily less concentrated between the 1950s and 1990s (perhaps with some retrenchment between the 1980s and 1990s), shown by flattening ECDFs for each succeeding decade. That trend reversed sharply in the 2000s, with the annual ECDFs approaching a right angle. In the 1980s the range of 15,000 to 30,000 roughly marked the 50^{th} percentile for annual trading volumes, with half of the listed contracts trading above that range and half below. By the 2000s that range had fallen to between 300 and 8,000.

Figure 6.2 itself highlights one likely cause of this shift - the explosion of innovation during the 2000s. The ECDFs for the 2000s are appreciably smoother than those of previous decades, with 2011 looking almost like a continuous function. This smoothness is due to the inclusion of additional contracts. Figure 6.3 directly displays the number of contracts with annual reported volume (which is allowed be zero) in the sample by year. It shows the same explosive trend in innovation discussed in Gorham and Kundu (2012), with over 3000 derivatives contracts reporting annual volume in 2011.

Probability of individual contracts moving to different levels of trading by decade

Figures 6.4 and 6.5 give the probabilities of individual contracts moving between volume levels in a given year t (indicated by the row of estimates) and volume levels in year t+1 (indicated by the column of estimates). These probabilities, estimated separately for each decade in the sample via equation 6.4, combine to form the transition matrix for a Markov model of a contract emerging over time.

The parameter estimates indicate that there is substantial inertia across every decade keeping contracts with a given level of trading volume at that same volume in the following year. In virtually all decades in the sample, contracts trading at or above 1,000 in annual volume were more likely to remain at their trading volume level than to move up or down. This dynamic is particularly strong at higher levels of trading. In most decades where relevant observations were available, contracts with annual volume of one million or above remained in that range the following year with probabilities between ∼80 and ∼90 percent (see lower right-hand corner of figure 6.5).

We also see substantial historical evidence of inertia at very low levels of trading. From 1970 until 2000, the median probability that a contract with trading volume of zero would remain at zero the next year, ranged between 80 and 95 percent (see upper left-hand corner of figure 6.4).

The transition matrix begins to depart from the prevailing story in Silber (1981) and Carlton (1984) when you look at contracts at lower levels of trading in the 2000s. (See the top rows of figure 6.4.) The inertia for those contracts is lower than in previous decades, with the median probability of a contract at an annual volume of zero remaining at zero falling to 70 percent (figure 6.6). While zero volume contracts remained unlikely in absolute terms to rise to higher volume levels, the 95 percent probability interval for the transition probability for the 2000s does not overlap with those for recent decades, meaning that the difference holds with high probability.

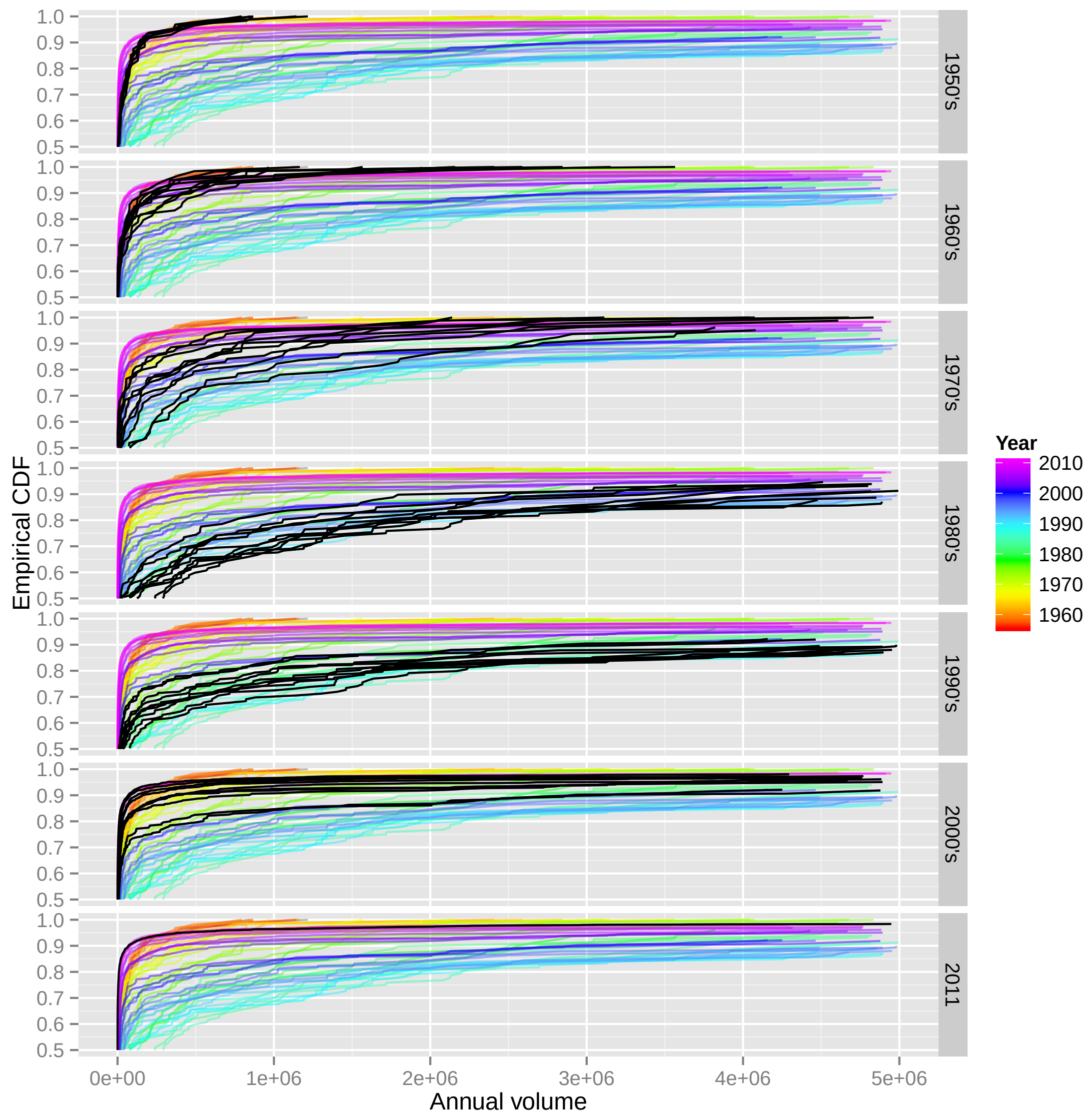


Figure 6.2: Empirical cumulative distribution function (ECDF) of annual trading volumes by contract with scale adjusted to distinguish between decades - Each line represents the ECDF for a different year. Each of the stacked panels highlights the years in a particular decade in black. Note that an ECDF approaching a right angle represents a year in which volume was concentrated in a few contracts. Hence, with some exceptions in the 1990s the market as a whole becomes less concentrated, until the 2000s when it abruptly becomes highly concentrated.

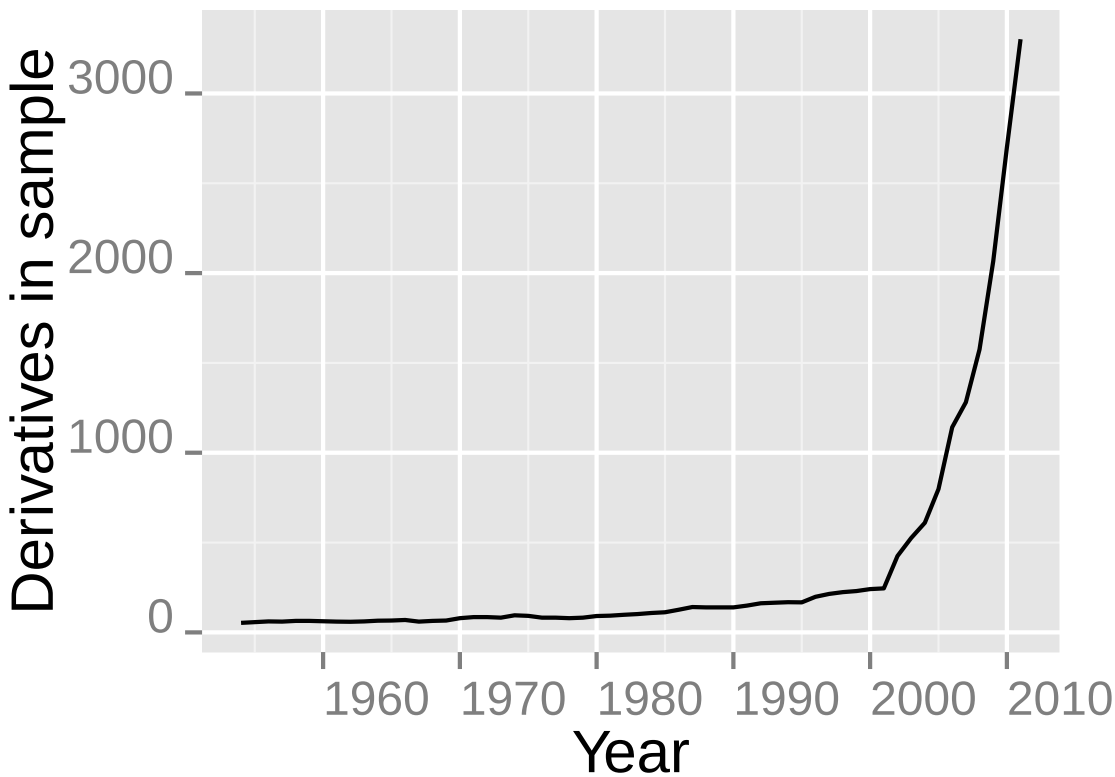


Figure 6.3: Number of contracts in sample by year

During the decade of the 2000s, contracts were substantially more likely to jump from an annual trading volume of 0 to trading volumes between 10 and 1000 than in previous decades. (See top row of figure 6.4 and 6.7.) Combined with the apparent trend toward maintaining rather than delisting contracts, this suggests that there was less path-dependence for trading volumes in the 2000s. While more contracts traded at a volume of 0 in any given year (see figure 6.2), contracts were substantially more likely to jump up from such low trading volumes in the 2000s.

Having reached annual trading volumes in the 10s or 100s (see 6.8), contracts in the decade of the 2000s were again substantially more likely to continue increasing their trading volume in the 2000s than in the 1980s or 1990s. Only after reaching trading volumes in the 1000s (figure 6.9) did the probability of an individual contract progressing to higher levels of annual trading volume fall roughly back within the same range as those from previous decades. In the 2000s, contracts generally moved up to annual trading in the thousands with an ease not seen in previous decades.

Contracts trading in the tens of thousands were 8 percent more likely to fall back to lower levels of annual volumes in the 2000s than in previous decades, a difference that holds with high probability. This indicates that some of the flexibility gained for contracts at lower levels of trading may have come at the expense of contracts at mid to high levels of trading. (However, as we see in figure 6.12, discussed below, that

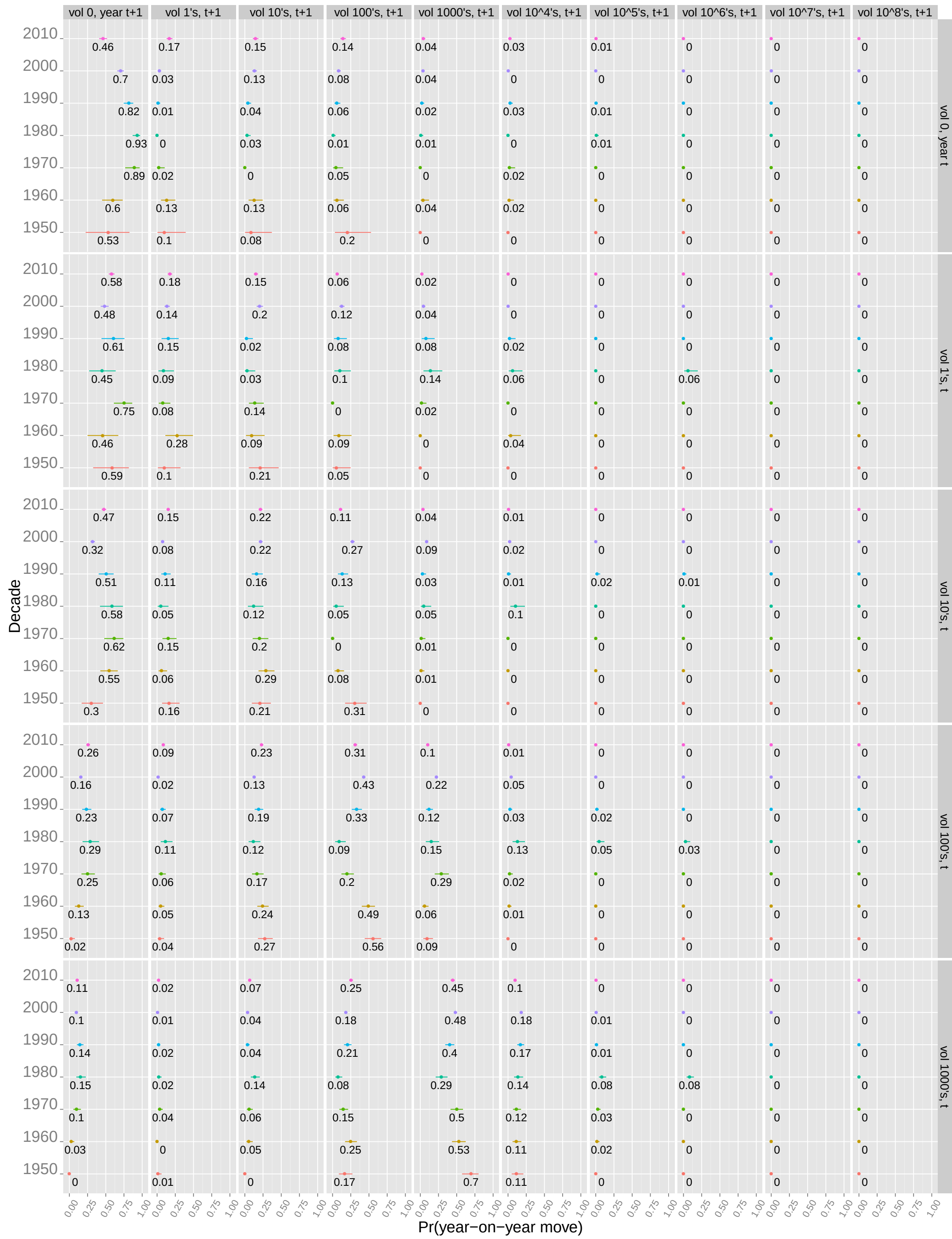


Figure 6.4: Transition matrix for Markov model of derivatives contract moving between states of annual trading volume by decade - row represents state in year t, column represents state in year $t+1$, median estimate indicated by dot, 95 percent probability interval indicated by line - part 1: transitions given annual volumes ≥ 0 and $< 10,000$

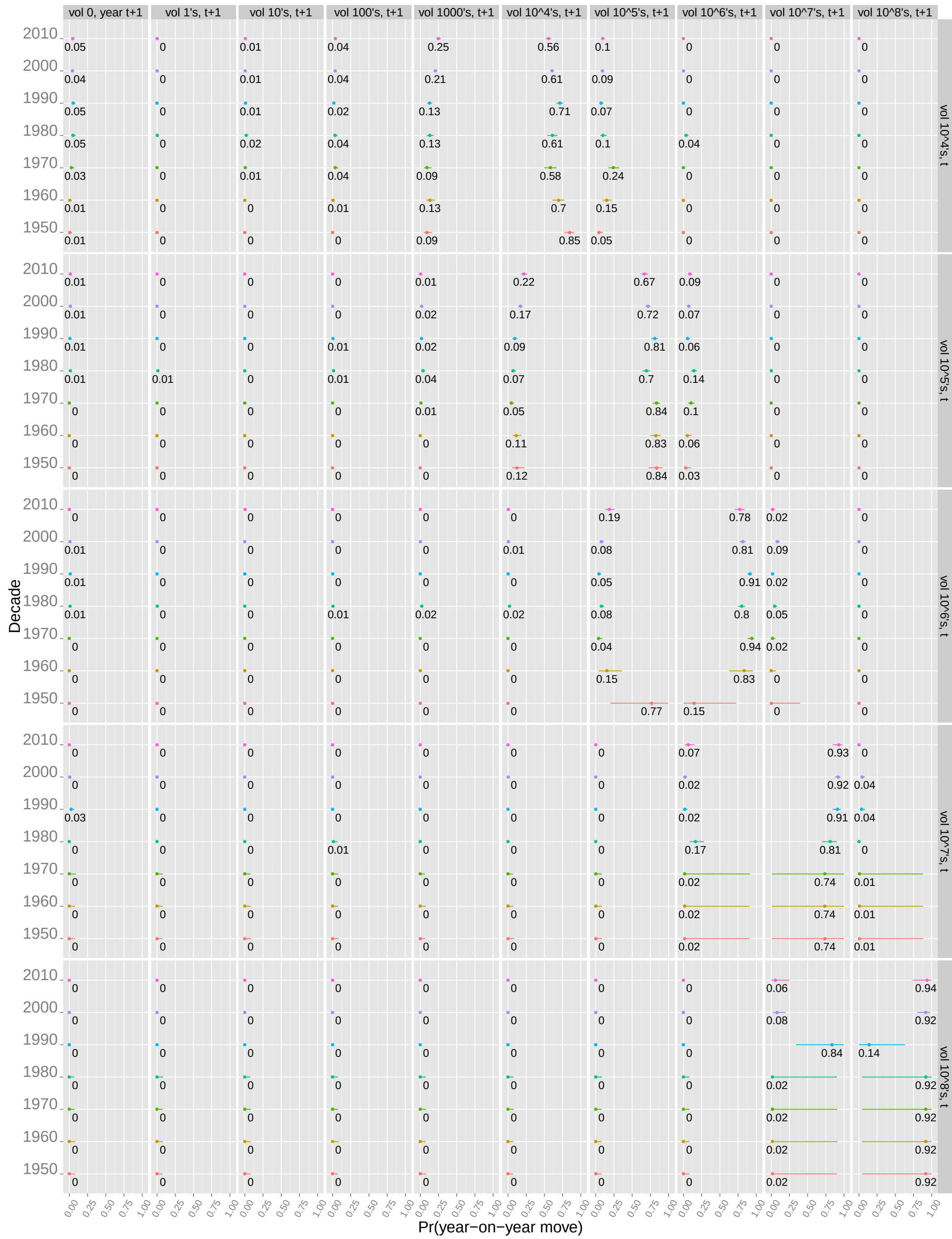


Figure 6.5: Transition matrix for Markov model of derivatives contract moving between states of annual trading volume by decade - row represents state in year t, column represents state in year $t+1$, median estimate indicated by dot, 95 percent probability interval indicated by line - part 2: transitions given annual volumes $\geq 10,000$

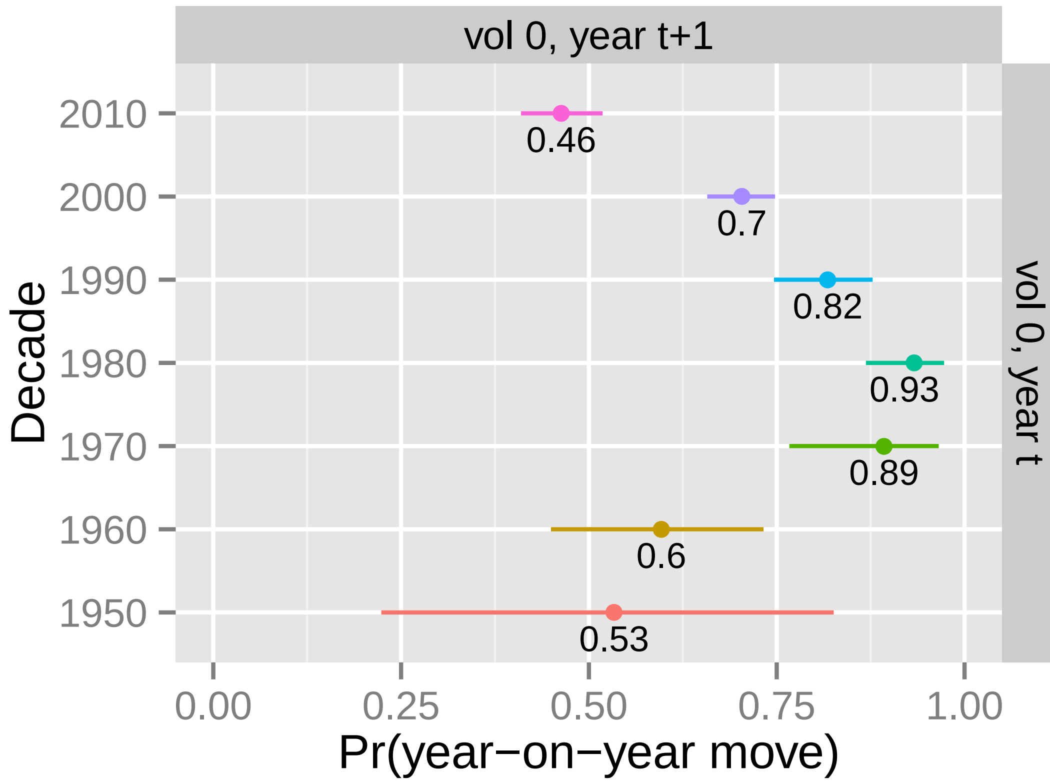


Figure 6.6: Probability of remaining at annual volume of zero from year to year by decade

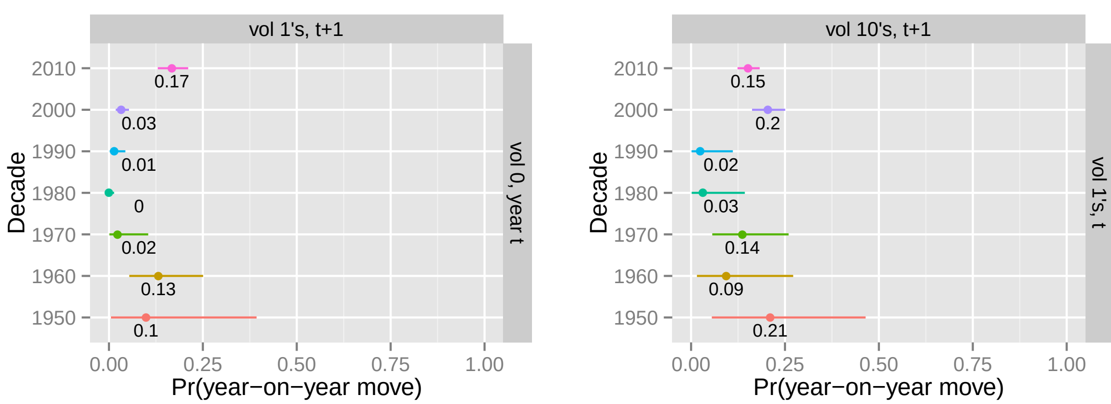


Figure 6.7: Probability of transition from annual volume of 0 to annual volume in the single digits (left) and from annual volume in the single digits to annual volume $\geq 10, < 100$ (right)

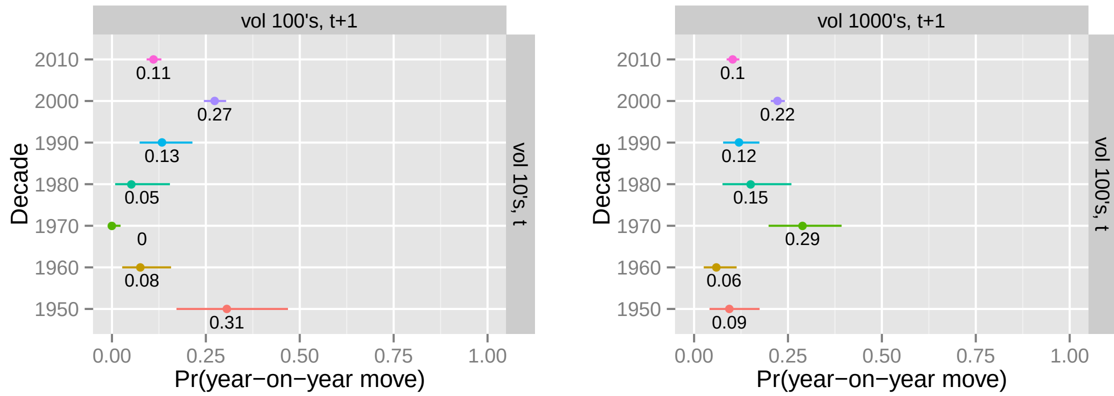


Figure 6.8: Probability of transition from annual volume in the hundreds to annual volume in the thousands (left) and from annual volume in the thousands to annual volume tens of thousands (right)

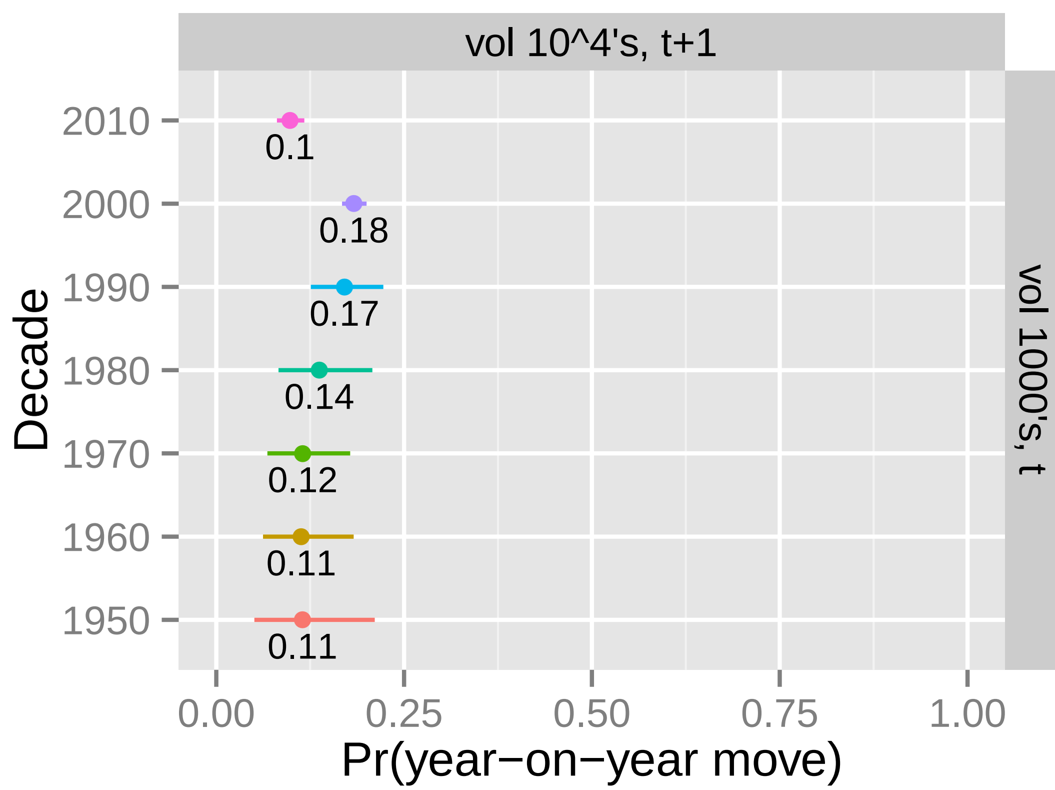


Figure 6.9: Probability of transition from annual volume in the tens of thousands to annual volume in the hundreds of thousands

Table 6.1: Median estimates of transition matrix between volume states on full sample - with annual trading volume state in year t denoted by row, trading volume state in year t denoted by column

volume level	vol 0's, t+1	1	10	100	1000	10^4	10^5	10^6	10^7	10^8
vol 0's, t	0.66	0.08	0.11	0.09	0.03	0.02	0.00	0.00	0.00	0.00
1	0.56	0.16	0.16	0.08	0.03	0.01	0.00	0.00	0.00	0.00
10	0.42	0.12	0.21	0.18	0.06	0.02	0.00	0.00	0.00	0.00
100	0.20	0.05	0.17	0.38	0.17	0.03	0.00	0.00	0.00	0.00
1000	0.10	0.01	0.05	0.20	0.47	0.15	0.01	0.00	0.00	0.00
10^4	0.04	0.00	0.01	0.03	0.19	0.62	0.10	0.00	0.00	0.00
10^5	0.01	0.00	0.00	0.00	0.02	0.14	0.74	0.08	0.00	0.00
10^6	0.01	0.00	0.00	0.00	0.01	0.01	0.08	0.84	0.04	0.00
10^7	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.90	0.03
10^8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.87

retrenchment from trading in the tens of thousands was not enough, on balance, to lower the prospects of a new contract over the course of ten years.)

Annual trading in the 10,000s appears to represent an important milestone for contracts across the sample. Having reached this level of trading, the likelihood of outright collapse (annual trading volume falling to 0 in the next year) fell to very low levels and was largely indistinguishable across the decades (figure 6.10). Table 6.1 presents the median estimates of transition probabilities estimated across the full sample (i.e. aggregating across decades). They show clearly that having reached annual trading of in the 10,000s, a full collapse becomes relatively unlikely (4 percent). In fact, for contracts that achieve annual trading in the 10,000s, the probability of falling more than one volume level is below 10 percent. (See the sixth row of table 6.1.) Note that these full sample estimates are biased toward recent decades because the sample contains more observations from recent decades.

As suggested above, one hypothesis regarding the recent shift in derivatives lifecycles is that the additional flexibility that low volume contracts enjoyed in the 2000s came directly at the expense of mid-range to higher volume contracts. In volatile markets, hedgers might be choosing niche contracts with lower basis risk over more liquid cross-hedges. What would that mean for the overall outlook for lifetime trading of derivatives? We test this by looking at the expected trading volume of a new derivative over the course of ten years.

Combining draws from the transition matrix in figures 6.4 and 6.5 with draws from a vector representing the probability of a contract starting in each of the available states of annual trading volume (estimated using the same basic model presented in equation 6.4) we can get the probability that a new contract will be in any given state of volume after ten years of trading. Those values are displayed in figure 6.11. Figure 6.11 makes clear the resilience of contracts trading at low levels in the 2000s. Only 32 percent of contract that debuted with zero volume were still trading at zero volume after ten years in the simulation representing the 2000s. Those probabilities

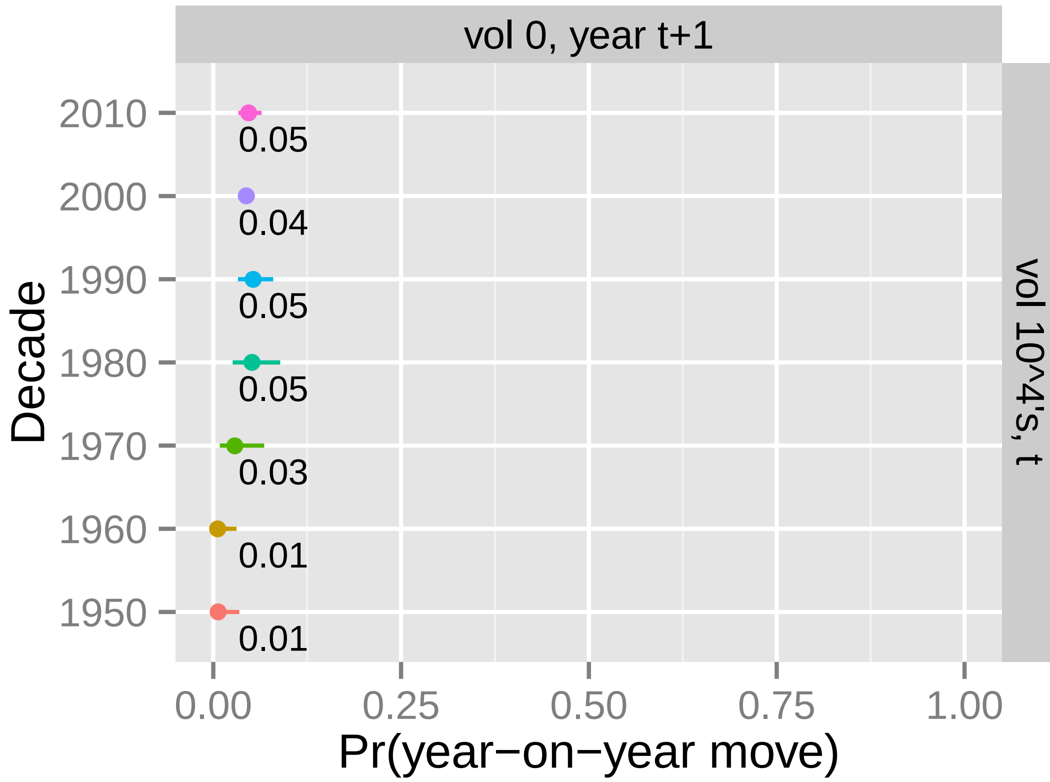


Figure 6.10: Probability of transition from annual volume in the tens of thousands to annual volume of 0

were 46, 48, and 52 percent in the 1990s, 1980s and 1970s respectively (See the first column of boxes in figure 6.11).[3] Instead of languishing, contracts simulated from the 2000s were more likely to migrate over ten years to moderate levels of trading. (See the columns of boxes in figure 6.11 corresponding to annual trading volume between 100 and 10,000.) Those same contracts were, however, less likely to reach the highest levels of trading ($\geq 100,000$) than contracts from other decades. The 1980s appears to be the best decade for such blockbuster contracts, as suggested in Gorham and Kundu (2012).

Simply comparing the raw probabilities of reaching various levels of volume after ten years, it is difficult to discern which decade provided a better overall environment for new contracts. To make that comparison, we normalize the probabilities in figure 6.11 by the lower bound of each trading range (i.e. multiplying the probability of being in the trading state ≥ 100 and $< 1,000$ by 100). This give an approximation of the expected trading volume of a new contract after ten years, displayed in figure 6.12. Based on that graph, we can conclude:

[3]Note these simulated values simply describe the dynamics of the transition matrices when compounded. They ignore delisting. If we accounted for delisting, a practice that was more common in previous decades, the probabilities of failure would likely be higher for those decades.

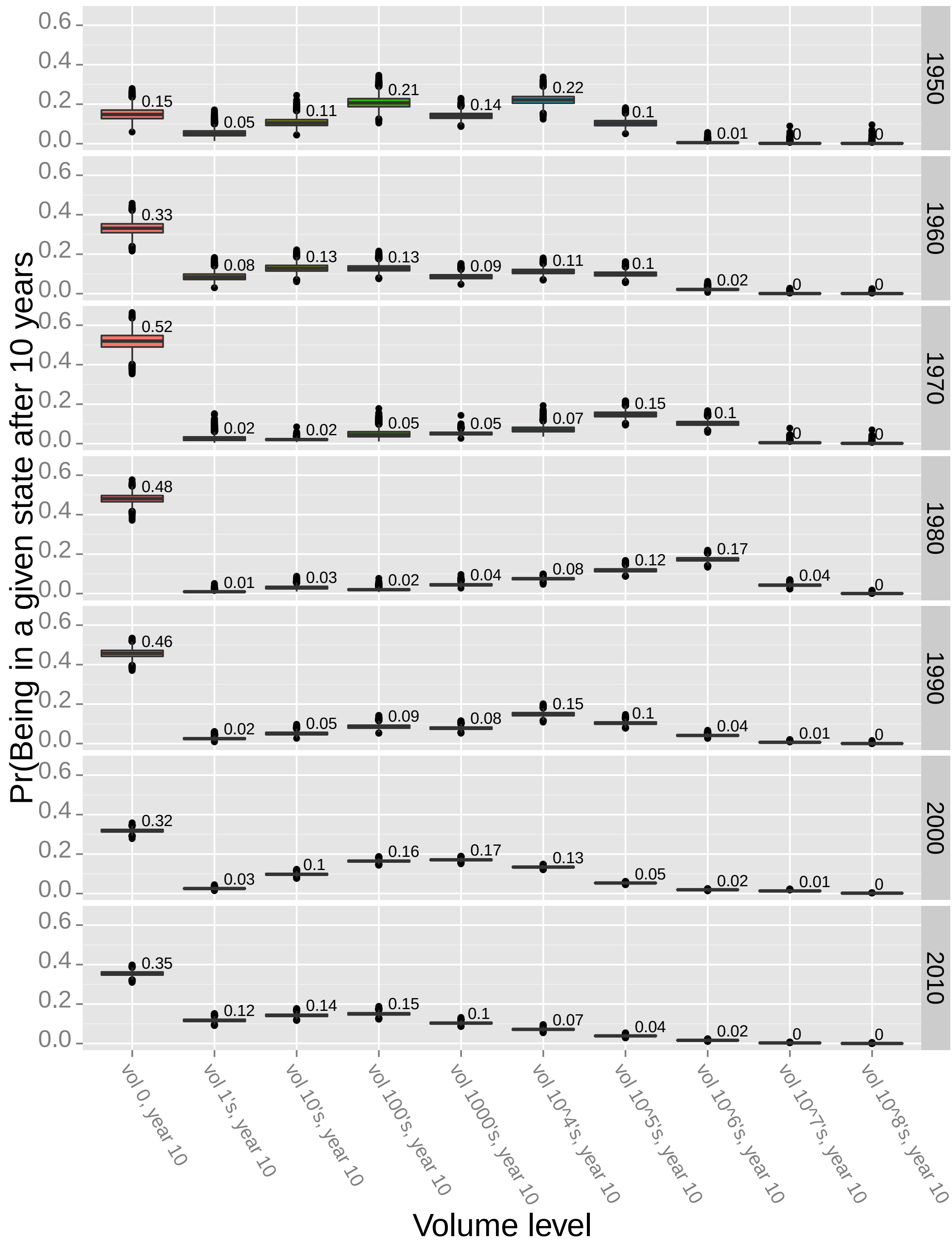


Figure 6.11: Box and whiskers plot of probability of a new contract being atp different levels of trading after 10 years by decade - median simulated probability marked in text, upper and lower hinges of the box plot correspond to the first and third quartiles (the 25th and 75th percentiles)

- The expected trading volume after 10 years for a contract has varied substantially from decade to decade;
- There is no clear trend that emerges from these variations over time;
- The expected trading volume at year ten for a contract in the 2000s was firmly in the middle of the historical range - the 2000s were lower than the 1980s, higher than the 1990s, and all three decades showed substantial overlap with the earlier decades in the sample;
- In the 2000s, low volume contracts tended to rise to modest levels of trading, balancing any fall in the probability of reaching the highest trading levels.

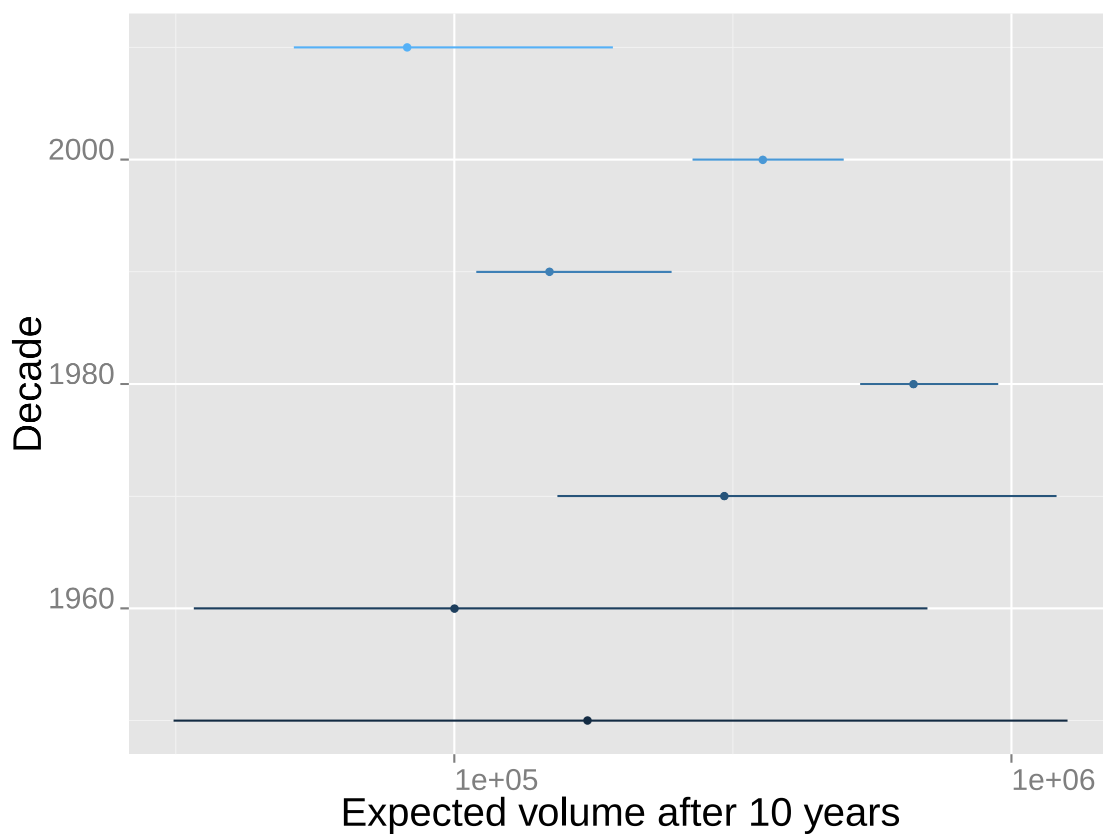


Figure 6.12: Expected trading volume over ten years by decade

While a larger percentage of contracts were at low volumes in the 2000s than in previous decades (figure 6.1), individual contracts were considerably more likely to jump up from very low volumes to moderate volumes (figure 6.7). The net effect of these trends set the expected volume of contracts at year ten well within the historical range of earlier decades (figure 6.12). This is remarkable given the explosion in the number of contracts launched (figure 6.3). It suggests that the marginal value of an innovative contract (approximated by its expected trading volume at year ten) did not fall in the 2000s, despite exponentially higher rates of innovation than in past decades.

This shift is consistent with the hypothesis that electronic trading made trading activity more mobile across derivatives markets and substantially cut the costs of launching and sustaining a derivatives contract. But changes went above and beyond the introduction of electronic trading on US and European exchanges in the 2000s, making it difficult to identify the causes of product lifecycle shifts in aggregate statistics. For example, many of the new contracts launched in the 2000s (and included in this sample) are bilaterally-negotiated, but centrally-cleared swaps. In the wake of Enron's collapse, which threatened energy firms with counter-party defaults on their swaps trades, exchanges launched popular new facilities devoted to these cleared-swaps, including the CME's ClearPort. While those contracts benefited from a suite of tools associated with electronic trading, they were not subject to electronic trading in the narrow sense of actually having buy and sell orders matched on an electronic platform.

To isolate the influence of electronic trading, we look at contracts trading on the New York Mercantile Exchange (NYMEX), where electronic trading was introduced suddenly. The NYMEX does not offer an ideal natural experiment. Its trading patterns were likely influenced by the shift toward cleared swaps throughout the 2000s. However, the abruptness of the exchange's switch to electronic trading does offer some scope for teasing out the relative import of electronic trading.

6.5 Derivatives volumes by exchange

Differences in trading volume patterns over the life of a derivatives contract may be influenced by the exchange offering the contract. Carlton (1984) hypothesized that economies of scale in designing and launching a contract gave those on larger exchanges a relative advantage in terms of trading volumes. Similarly, there may be network effects stemming from an exchange's ability to cross-margin trades.

Cuny (1993) and Holland and Fremault (1997) suggest that innovative exchanges may enjoy a first-mover advantage, capturing a disproportionate share of trading on those contracts that they launch. Gorham and Kundu (2012) tests this hypothesis and finds little persistent advantage. In the context of a Markov model of trading volumes, if indeed there is a first-mover advantage, then we would expect innovative exchanges to distinguish themselves with higher expected trading in year ten.

Figure 6.13 presents expected volume in year ten for contracts on all exchanges in the sample. Contracts show greater distinction across decades (as in figure 6.12) than across exchanges. It is possible to distinguish individual exchanges from one another. For example, contracts on the Chicago Board of Trade have an advantage over those on the NYMEX in expected value terms. But no exchanges clearly distinguish themselves from the general tendency with greater than 95 percent probability. Possible exceptions include:

- the single-stock futures traded on OneChicago which show particularly low expected trading volumes over ten years

- the two registered exchanges in the IntercontinentalExchange group, marked ICE and ICEU in figure 6.13, which likely have higher expected trading volumes than most other exchanges. It is important to note that these exchanges specialize in OTC markets, only a handful of which have been reported to the CFTC as futures. Consequently, some of their performance may represent selection bias.[4]

CME acquisitions test the important of exchange to lifecycles

Recent exchange acquisitions offer the chance to test the effects of particular exchanges on trading volumes. Gorham and Kundu (2012) singled out the CME as the exchange with a persistent advantage over its rivals - leading other major exchanges in mean volume in the 5th year of trading, mean lifetime volume, and their approximations of present value discounted fee generation. In the late 2000s, the CME Group effectively[5] took over both the New York Mercantile Exchange (designated in the database as NYME but commonly referred to as the NYMEX) and the Chicago Board of Trade (CBT). After the acquisitions, the exchanges' contracts continued to be reported as before (i.e. NYMEX contracts continued to be reported in the dataset as NYMEX contracts).

If indeed the CME did enjoy a persistent advantage on multiple volume metrics, then presumably the transition matrices for NYMEX and CBOT contracts, calculated using the Markov models profiled here, would improve following their acquisitions. These acquisitions could also test a weaker form of that same hypothesis. If exchange management is important to contract lifecycles, then the CBOT and NYMEX's contracts' transition matrices should converge to the CME's, regardless of whether the CME has an advantage over other exchanges or not.

Figures 6.14 and 6.15 for the NYMEX and Appendix B: Lifecycle Appendix's figures 14 and 15 present the transition matrices for each of the merged exchanges in the years before and after the merger.[6]

The CBT's transition matrices (Appendix B: Lifecycle Appendix's figures 14 and 15) show no consistent trends in post-merger years relative to the earlier years in the sample. Post-merger years with strong performance (contracts showing a high probability of advancing to a higher level of liquidity - such as 2010, where many of the contracts previously trading with annual volumes in the thousands advanced to the tens of thousands) do not stand out relative to the pre-merger era. To the extent that the CBT shows any post-merger trend, it stems from 2010, an especially

[4] In late 2012, the IntercontinentalExchange announced that many of its most popular OTC contracts will begin trading as futures.

[5] Technically, the CME and CBOT merged. However, the CME was the dominant firm in the merger, initiating the transaction and retaining most of the key staff positions. Olson (2010) provides an inside account of the fight between the CME and ICE for control of the CBOT.

[6] We chose to present the full transition matrix for the exchange-year comparisons rather than the expected value figures because we believe that the former provide more robust inference. Expected value calculations are sensitive to the initial trading volumes of the contracts that happened to launch after the merger.

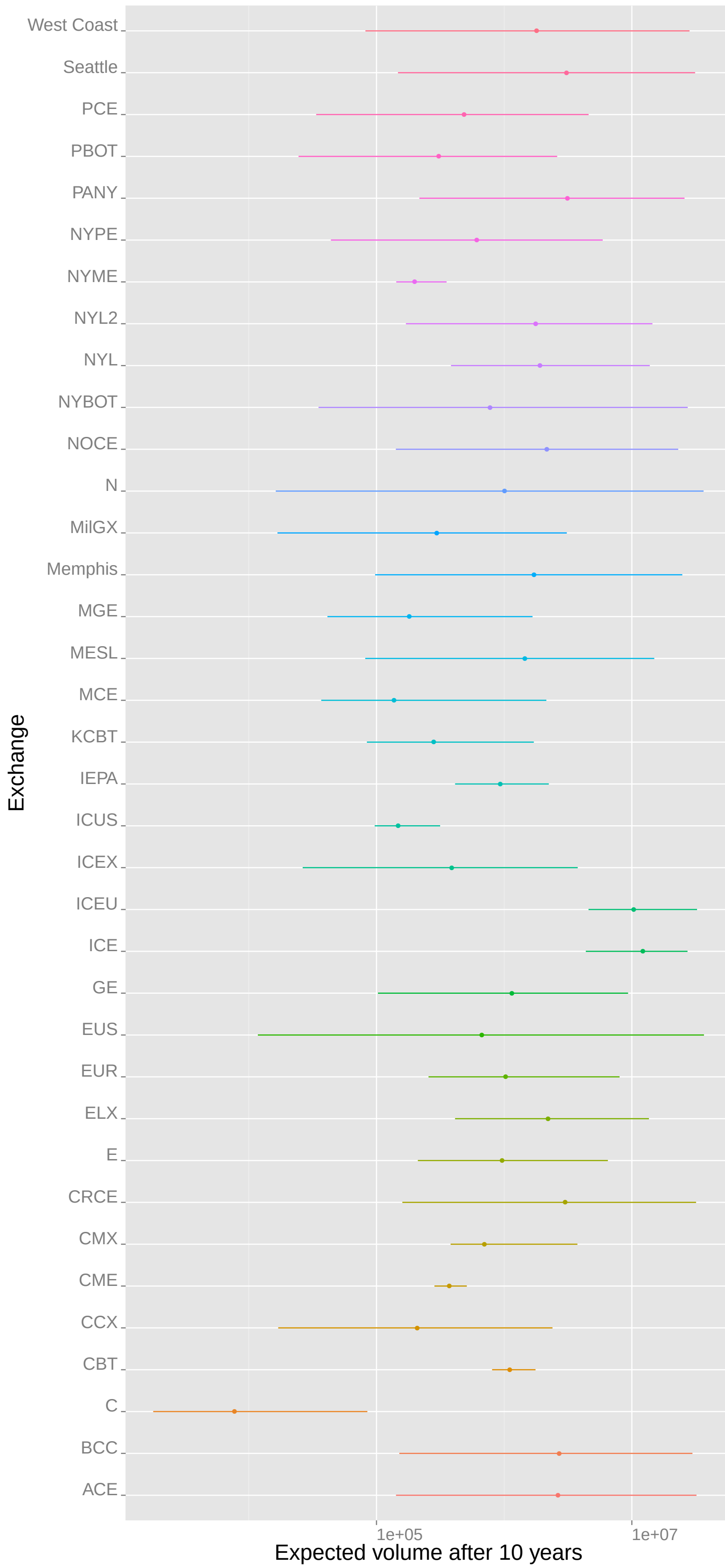


Figure 6.13: Expected trading volume over ten years by exchange

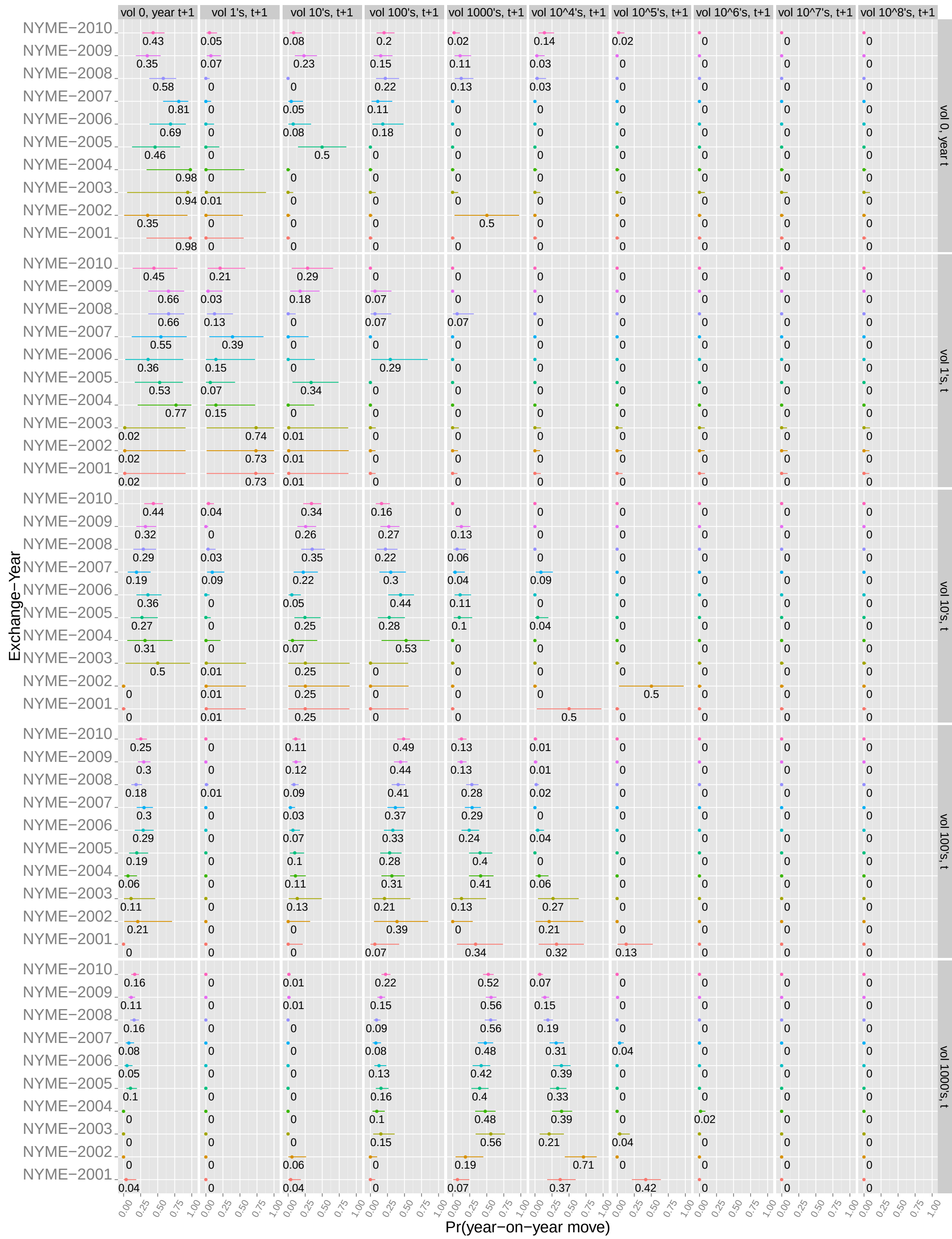


Figure 6.14: Transition matrix for Markov model of derivatives contract moving between states of annual trading volume by decade - NYMEX before and after CME merger (announced March 2008, finalized September 2009) and before and after switch to electronic trading (September 2006) - part 1: transitions given annual volumes ≥ 0 and $< 10,000$

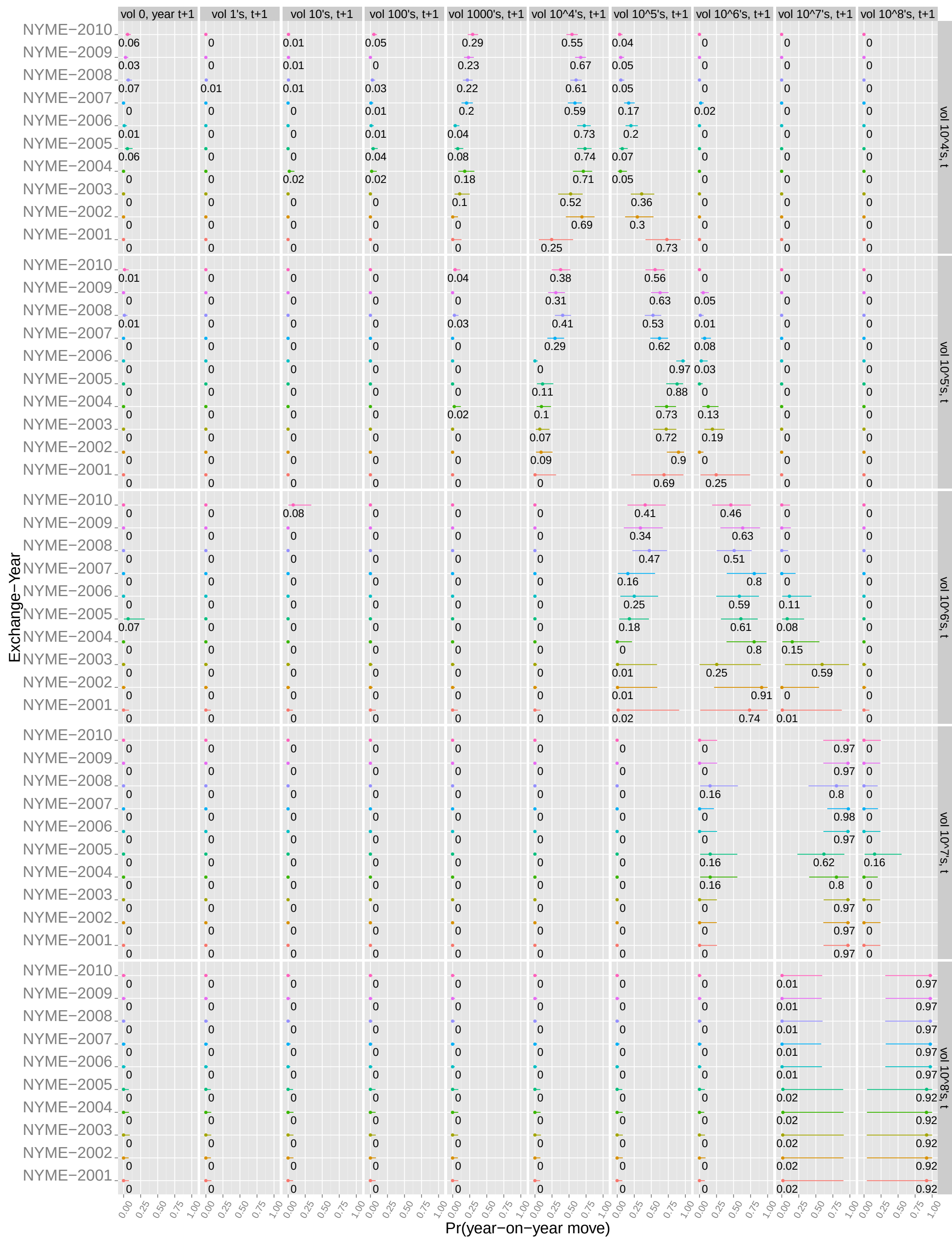


Figure 6.15: Transition matrix for Markov model of derivatives contract moving between states of annual trading volume by decade - NYMEX before and after CME merger (announced March 2008, finalized September 2009) and before and after switch to electronic trading (September 2006) - part 2: transitions given annual volumes $\geq 10,000$

volatile year for the CBT, where many contracts advanced to trading in the tens of thousands and a particularly large percentage fell back from annual volumes in the tens of thousands.

Unlike the transition matrix for the CBT, the NYMEX shows a clear trend in its transition probabilities. On the rows in figures 6.14 and 6.15 indicating trading volume between ≤ 10 and $< 1,000,000$ (rows three through five in figure 6.14 and rows one and two in figure 6.15), a gradual pattern in volume level transitions emerges that is strong enough, by the end of the decade, to hold with high probability. Starting roughly in 2006, the 10s, 100s, and 1000s became sinks (rows three through five in figures 6.14). The probability of staying at these levels year on year increases gradually. The probability of rising out of that range falls. At levels immediately above that sink (rows one and two in figures 6.15), the probability of falling into the sink rises at the clear expense of the probability of staying put or rising. This trend predates, and is uninterrupted by, the CME merger.

Neither transition matrix support the hypothesis that exchange management is an important factor in lifecycle patterns, much less the hypothesis that CME's systems and network effects boost trading volumes substantially relative to competing exchanges.

Recent trends in NYMEX lifecycles and the importance of electronic trading

While they do not show a strong influence from the CME acquisition, figures 6.14 and 6.15 may speak to the influence of electronic trading. Pronounced lifecycle trends on the NYMEX seem to begin in 2006, when the exchange abruptly switched from open-outcry to electronic trading. These trends mirror the more general tendency across derivatives markets over the last decade, with more flexible trading at low volumes, more contracts moving up to modest volumes, and a small decline in the probability of trading at high levels.

As mentioned above, it is difficult to separate out the effects of electronic trading per se from those of the whole suite of new tools that arrived with electronic trading, such as clear swaps platforms. NYMEX, within its specialization in energy contracts threatened by Enron, was a pioneer in cleared swaps transactions. In 2003, it launched ClearPort, the platform now used for all of the CME's cleared swaps trades. ClearPort was marketed as an *electronic trading system* because it disseminated information about specialized swaps trades via screens (Reuters News, 2003). However, most cleared swaps transactions are negotiated bilaterally, over the phone. That means that ClearPort trades are supported by electronic infrastructure, but they are not fully electronic. So, while NYMEX's abrupt shift from pit-based to electronic trading offers a prime opportunity to isolate the influence of electronic trading on derivatives volumes, the advent of cleared swaps complicates both the analysis of NYMEX data and the definition of electronic trading.

To the extent that we can identify the influence of fully electronic trading on its own, then 2006, the year that NYMEX abruptly closed pit trading, should produce discontinuities in ongoing lifecycle trends. 2006 does indeed show evidence of a discontinuity. That evidence is not overwhelming, but it does support the hypothesis that the large changes in derivatives markets in the 2000s were driven specifically by the switch to electronic trading.

6.6 Derivatives volumes by product type

Figure 6.16 shows expected value estimates for trading at year ten for each product type. Derivatives based on US treasuries, and, to a lesser extent, derivatives based on natural gas and stock indexes enjoy higher expected volumes than other product types.

The distinction between these strong performers and most of the other product types in the sample is appreciable but does not hold with high probability. The 95 percent probability interval for each of those high expected volume product types sits within the upper tails of the distributions for other product types. The long upper tails that shadow the three top performers are largely a function of uncertainty in estimating the parameter for relatively uncommon product types rather than stellar historical performance. They reflect the fact that we have relatively few observations of derivatives based on wood products, for example, and so our model allows for the possibility that out-of-sample wood products may show high trading volumes in the future.

Major currencies, grains, precious metals, petroleum-related products, and interest rates not derived from US treasuries define the middle of the pack for expected year ten volumes. They are joined by a large group of product types whose expected volumes are subject to great uncertainty, thanks to a scarcity of data.

Among these average performers, plastics and chemicals may be promising niches for innovation. While their estimated expected volumes are subject to considerable uncertainty, the data points we have indicate that they are relatively strong performers.

On the low end of our expected year ten volume estimates are single-stock futures[7] and weather derivatives. Both are relatively new product types with many correlated contracts launched in recent years. Interestingly, these contract types appear to under-perform relative to some product types like yield insurance and emissions in which trading was effectively smothered by external events (the proliferation of subsidized crop insurance in the US in the case of yield insurance and the failure of the US to consistently promote cap-and-trade legislation in the case of emissions).

Interestingly, single-stock futures and weather derivatives were more likely than most other product types to climb up from low levels of trading volume. Figures 6.17 and 6.18 present the probability of any contract moving to higher levels of annual trading volume for each product type in the sample. Single-stock futures are particularly likely to recover from years of zero trading volume and weather derivatives are particularly likely to move up to annual trading volumes in the thousands. (See Appendix B: Lifecycle Appendix's figures 9 and 10 for additional details.) Insofar

[7] This is consistent with figure 6.13 which shows OneChicago, the exchange specializing in single-stock futures as a relative under-performer in expected trading volume at year ten.

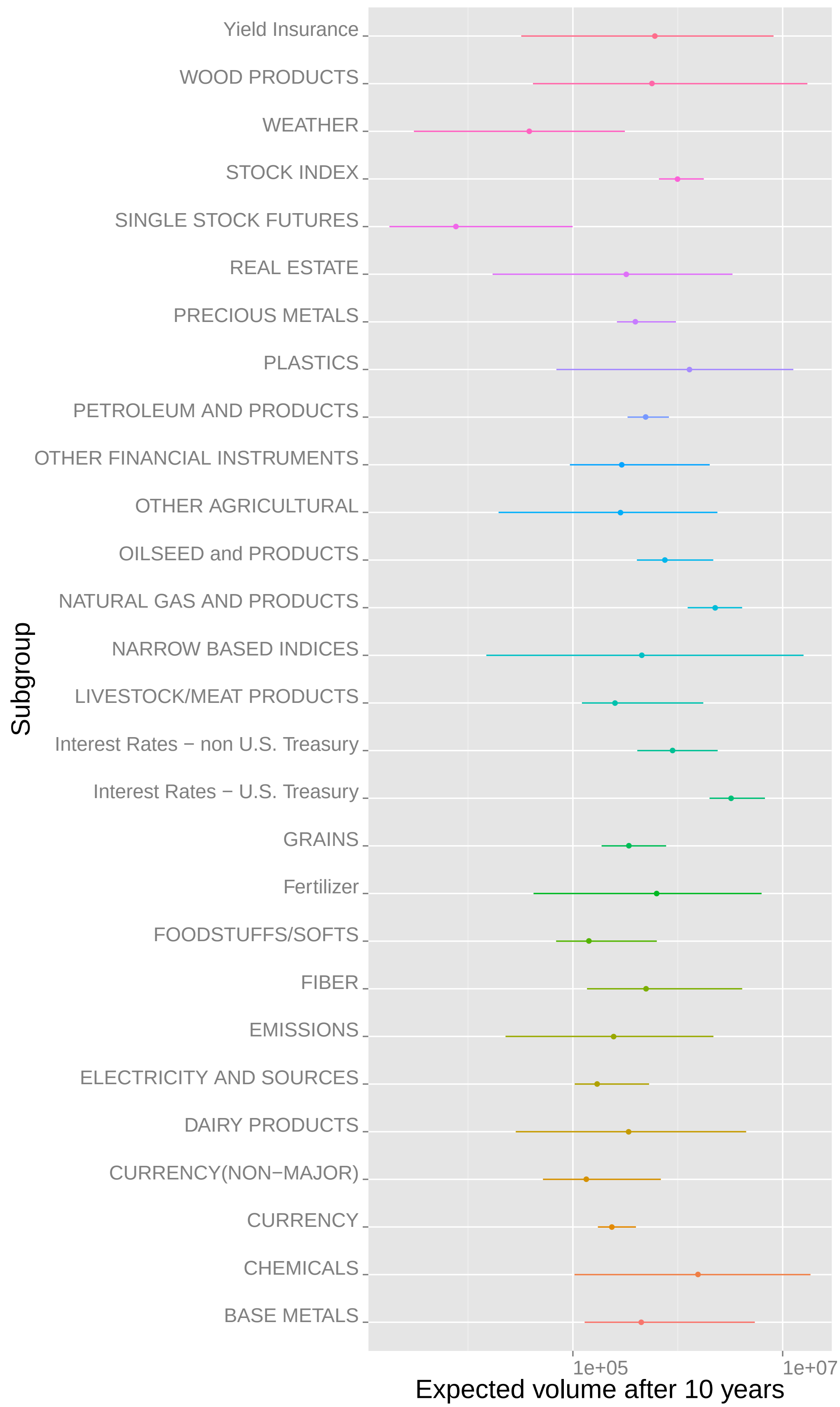


Figure 6.16: Expected trading volume over ten years by product type

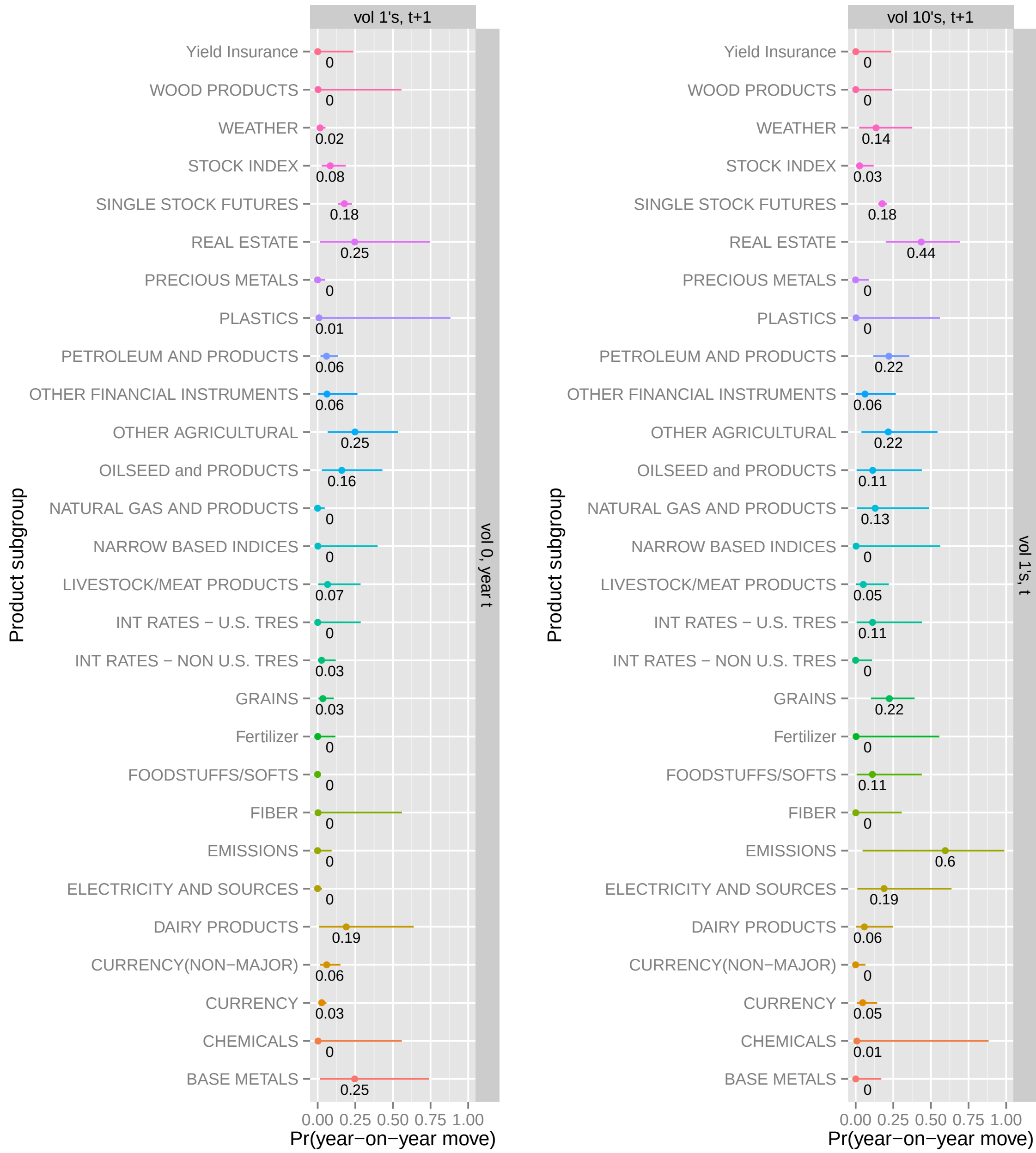
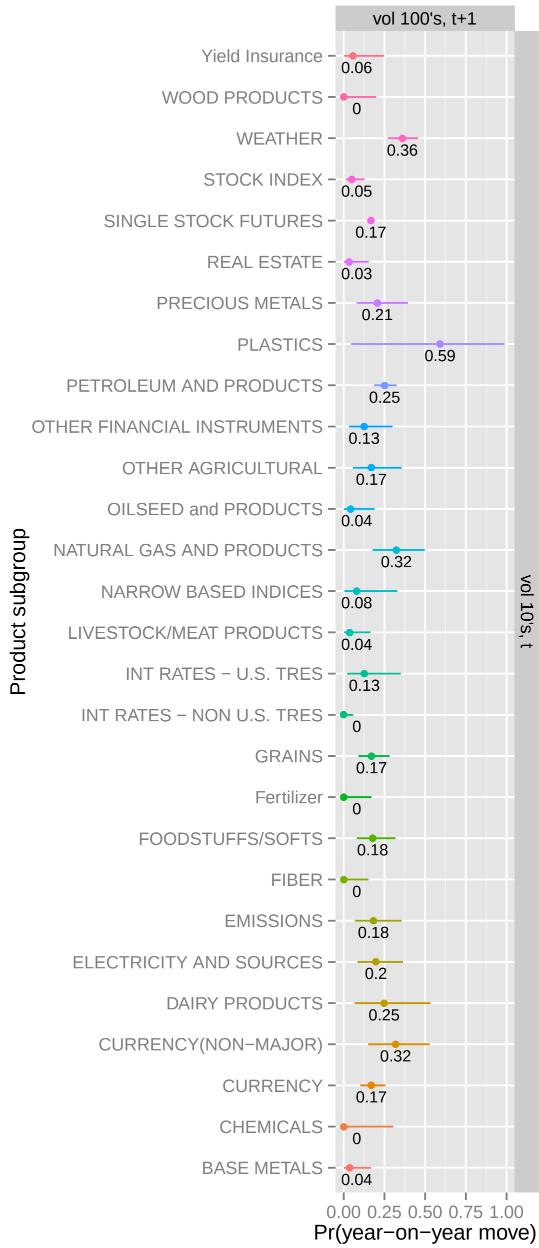


Figure 6.17: Probability of transition from annual volume in the hundreds to annual volume in the thousands (left) and from annual volume in the thousands to annual volume tens of thousands (right) by product type



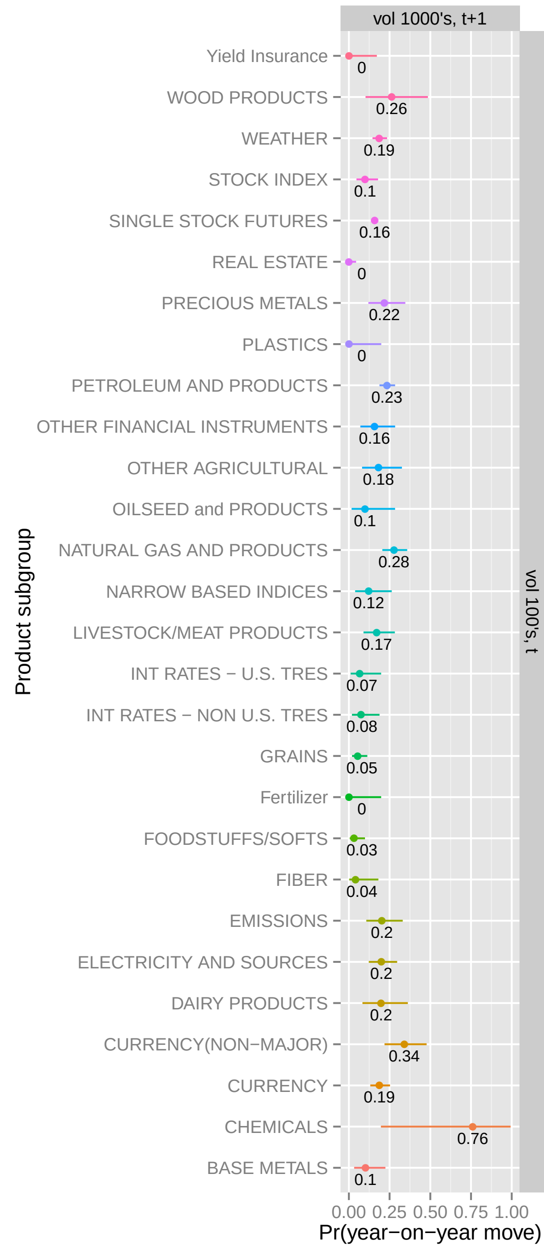


Figure 6.18: Probability of transition from annual volume in the hundreds to annual volume in the thousands (left) and from annual volume in the thousands to annual volume tens of thousands (right) by product type

as these product types move fluidly up and down from low levels of annual trading volumes they are representative of recent trends across derivatives markets.

6.7 Conclusions

In this article we have presented a comprehensive analysis of trading volumes for derivatives reported to exchanges in the United States. Looking across decades, exchanges, and product types we see multiple trends that challenge or significantly modify findings of existing studies.

While a larger percentage of contracts had little or no volume in any given year of the 2000s, contracts did not fail at the high rates noted in previous analyses. Instead, they remained at low levels of trading until they were needed, transitioning back into active trading with greater probability than in previous decades. Interestingly, this flexibility from low levels of trading meant that the long term outlook for a new contract did not erode despite remarkable levels of new contract innovation. During the 2000s the expected volume of a new contract after ten years was above that of the 1990s and within the range of previous decades. On balance, the explosion of innovation catalyzed by electronic trading did not hurt the prospects for the marginal contract.

We find that expected year ten trading volumes varied more decade to decade than from exchange to exchange or product type to product type. In particular, the lifecycle of a derivative on any given exchange was largely indistinguishable from that on any other, with the likely exception of OneChicago, which specializes in single-stock futures.

We find evidence that the decadal changes in derivative lifecycles were driven by the switch to electronic trading rather than the consolidation of exchanges by looking at trends on the New York Mercantile Exchange. The effects of electronic trading are difficult to separate from the the related innovation of cleared swaps. However, trends in NYMEX volumes following the 2006 launch of widespread electronic trading tentatively support the hypothesis that electronic trading is indeed driving recent trends in derivatives lifecycles across all sampled markets.

The statistical characteristics of derivative volumes

In addition to facilitating quick distributional comparisons across various contract groupings (decade, exchange, and product type), our framework (Markov models) allows us to explore some basic questions about derivative markets in general. For example, based on our Markov models it appears that trading volumes do not follow a normal or log-normal random walk over time. In figures 6.4 and 6.5 it is clear that the probability of remaining at a given level of annual volume varies dramatically from one level to the next. These differences hold with greater than 95 percent probability as do variations in the volume dynamics across time (indicating that normal or log-normal models of trading volume would suffer from stationarity problems as well). Furthermore, switches to higher and lower levels of trading are often not symmetric.

In particular, an outright crash to zero trading volume appears more likely than would be predicted by a symmetrically distributed random walk.

However, our analysis does affirm the common observation that it is unusual for a contract to experience initial popularity and to crash subsequently (Johnston and McConnell, 1989). After reaching a trading volume in the tens of thousands, the probability that a contract will have annual trading volume of zero in the subsequent year drops appreciably.

Optimal contract innovation

Much of the literature on derivative innovation focuses on the problem of choosing the optimal derivatives contract to launch next. This analysis does not directly address that question, but it does present some trends relevant to previous theoretical work which could inform further investigation.

One interpretation of Duffie and Jackson (1989) provides that revenue maximizing marginal innovations are uncorrelated with existing contracts. However, recent trends suggest that one of the key assumptions underlying this finding only holds weakly. Historically, correlated contract innovations have not shown diminishing marginal volumes. In general, innovation in derivatives markets has exploded in the last decade seemingly without dragging down expected trading volumes at year ten. Indeed, some of the highest volume product types (in expected volume terms) are highly correlated both to other derivatives of their product category but also to the average returns of the economy as a whole (US treasuries and stock indexes).

Tashjian and Weissman (1995) explains the proliferation of correlated (and often redundant) contracts as a form of price discrimination. They assume, that an exchange can charge higher fees on the transaction for parties with larger and more concentrated exposure to a given underlying index. This framework for understanding product innovation holds up well in light of recent trends. As we have discussed, many recently launched contracts are cleared swaps, which tend to be more specialized than conventional futures or options. As Tashjian and Weissman (1995) predicted, exchanges charge a substantial premium on these specialized transactions. Fees on CME's ClearPort platform were more than 350 percent those on conventional electronic futures trades as of late 2012 (CME Group, 2012). However, Tashjian and Weissman (1995) suggested that exchanges would charge more for single-asset-based derivatives (such as gold) than for derivatives that represented the holding of multi-product firms (like the crack-spreads used to reproduce petroleum refiners' returns). In practice, cleared-swaps contracts, with their relatively high fees, appear to be biased toward the latter.

A third explanation of recent patterns in derivative innovation is psychological. Based on Tversky, Kahneman et al. (1981), Shiller (1994) suggests that a hedge "appears more attractive when it's presented as the elimination of risk rather than when it is described as the reduction of risk." This tendency to overvalue hedges tailored to the needs of specific firms may explain the proliferation of correlated contracts (and their relative success) above and beyond the price discrimination suggested in Tashjian and Weissman (1995).

What kind of economic goods are derivatives?

The present analysis could also suggest new ways of understanding the economic value of derivatives. If indeed derivatives are simply contingent contracts that move cash flows across time and states of nature, then they should derive all their value from the way that they mesh with hedger's risk preferences. It follows from that idea, that if risk preferences remain stable over time, then derivative trading patterns should also remain stable.

But trading patterns have not been stable over the last decade. Instead, they bear a striking qualitative resemblance to those of information goods, particularly media:

- Each class of economic goods was, until recently, simple to classify: normal goods with elastic demand and network effects.
- Starting a new derivatives market, just like producing a new music album or launching a magazine, was a high risk, high reward proposition.
- In the last decade both saw paradigm shifts in their marginal cost structure (i.e. there were fundamental changes in supply).
- At the same time, new technologies allowed consumers ubiquitous access to goods (i.e. there were also fundamental changes in demand).
- After those twin revolutions, markets:

    - Rewarded specialty products more than in the past;

    - Hosted blockbusters as large as/larger than ever;

    - Did not offer the same opportunities for strong but less-than-blockbuster products.

In media (and informational goods more generally) this transition has upended many long-profitable business models and catalyzed a great deal of innovation. In derivatives it has certainly opened up the door to many new entrants like ICE, which now is one of two large futures exchanges in the US today. But it is not clear whether those new entrants are using fundamentally new business models.

How strong is the parallel? Should economists study derivatives alongside informational goods? What does the possible connection suggest for the future of derivatives? We believe that these questions provide a solid foundation for future research.

Chapter 7

Traded Catastrophe and Weather Markets Today

For decades economists and financial professionals have worked to move insurance-like risks to traded markets, often motivated by the same reasoning I discussed chapter 5. A few of those projects came up in my interviews over and over again. This chapter provides some basic information on those existing catastrophe and weather markets. It provides a context for the interviews that follow in chapter 8. For more detailed treatment of these markets, see Kurtov (2010) and Lane (2012).

7.1 Natural hazard catastrophe bonds

A catastrophe bond (CAT bond) is a securitized form of reinsurance risk.[1] They provide large chunks of tail-risk coverage, usually to individual insurance companies. While closely associated with the reinsurance industry, they are regulated and traded like bonds.

In its most simplified form, a CAT bond resembles a normal corporate bond. A bond *sponsor* receives a loan from the bond investors, which they must pay back, usually over the course of three years. The important distinction from a corporate bond is in how the initial loan gets put to work. In the case of a CAT bond, those initial funds are held in escrow until there is a *triggering* event, such as a hurricane of a given magnitude making landfall in a given region (a parametric trigger) or losses in a reinsurance portfolio exceeding a pre-specified level (an indemnity trigger). Setting up those escrow accounts, and establishing rules for how the funds are used while they are in escrow, makes the process of issuing a CAT bond a great deal more complicated than that simple example. But the basic notion holds. Capital markets provide funds that are set aside in the case of a disaster and are compensated by regular payments from the firm receiving coverage. If there is no triggering event, the investor receives both the principal of their loan and the full set of coupon payments. If there is a triggering event, the loan is effectively forgiven and provides the sponsor with a large, insurance-like payout.

One of the first CAT bonds was issued in 1997 on behalf of the insurance company USAA. Through that deal, dubbed the "bet with God" in the financial press (Quinn, 1999), USAA covered remote losses that reinsurers then considered too risky. Figure 7.1 reproduced from Froot (2001) shows how insurance companies like USAA actually had less reinsurance coverage for extreme events that would jeopardize their solvency

[1] Unfortunately, the world of financial engineering for catastrophe risk uses overlapping terms to describe itself. CAT bonds are the largest component of Insurance-Linked Securities (ILS), which in turn is form of alternative reinsurance capacity. Alternative reinsurance capacity is itself a subset of Alternative Risk Transfer (ART). Throughout this dissertation I used ILS and CAT bonds interchangeably.

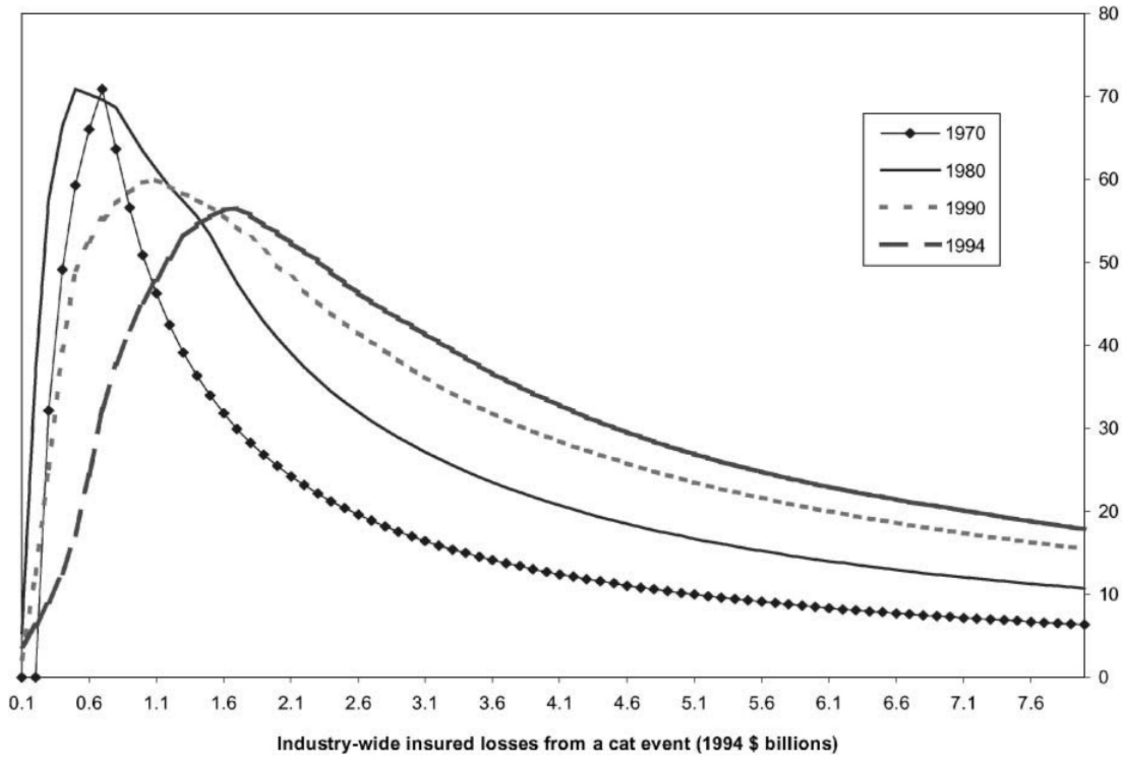


Figure 7.1: *Percentage of exposure that insurance companies reinsure (by various event sizes). This graph shows the amount of a marginal dollar of industry-wide loss that is reinsured against catastrophic losses in a sample of insurance companies that purchase reinsurance through Guy Carpenter & Company* - Figure and caption from Froot (2001). The long right tail on the graph shows that the industry held less reinsurance coverage for larger impact events.

than for higher-probability, lower-impact events. The long right tail on the graph shows that reinsurance companies *self-reinsured* (i.e. saved) against exactly those extreme risks that would threaten their solvency. USAA was intent on obtaining that extreme coverage and was willing to wait though a four year development process for its first CAT bond, probably at significant cost to the firm.

Since the first CAT bond transactions in the late 1990s, the market for alternative reinsurance capacity, which includes instruments like collateralized reinsurance and sidecars as well as insurance-linked securities (ILS) like CAT bonds, has grown to roughly 15 percent of the overall reinsurance market. Figure 7.3 shows that CAT bonds are the largest single source of alternative reinsurance capacity, at $\tilde{5}$ percent of total reinsurance capacity. The ILS market now has an outstanding notional value of roughly USD 17 billion (see figure 7.4). At those levels, CAT bond markets sustain a niche of asset managers dedicated to catastrophic risk, as shown in figure 7.5.

While the initial transactions were meant to augment reinsurance coverage, CAT bonds have become an alternative to reinsurance in some cases. Some industry insiders believe that the competition created by CAT bonds may change the pricing cycle

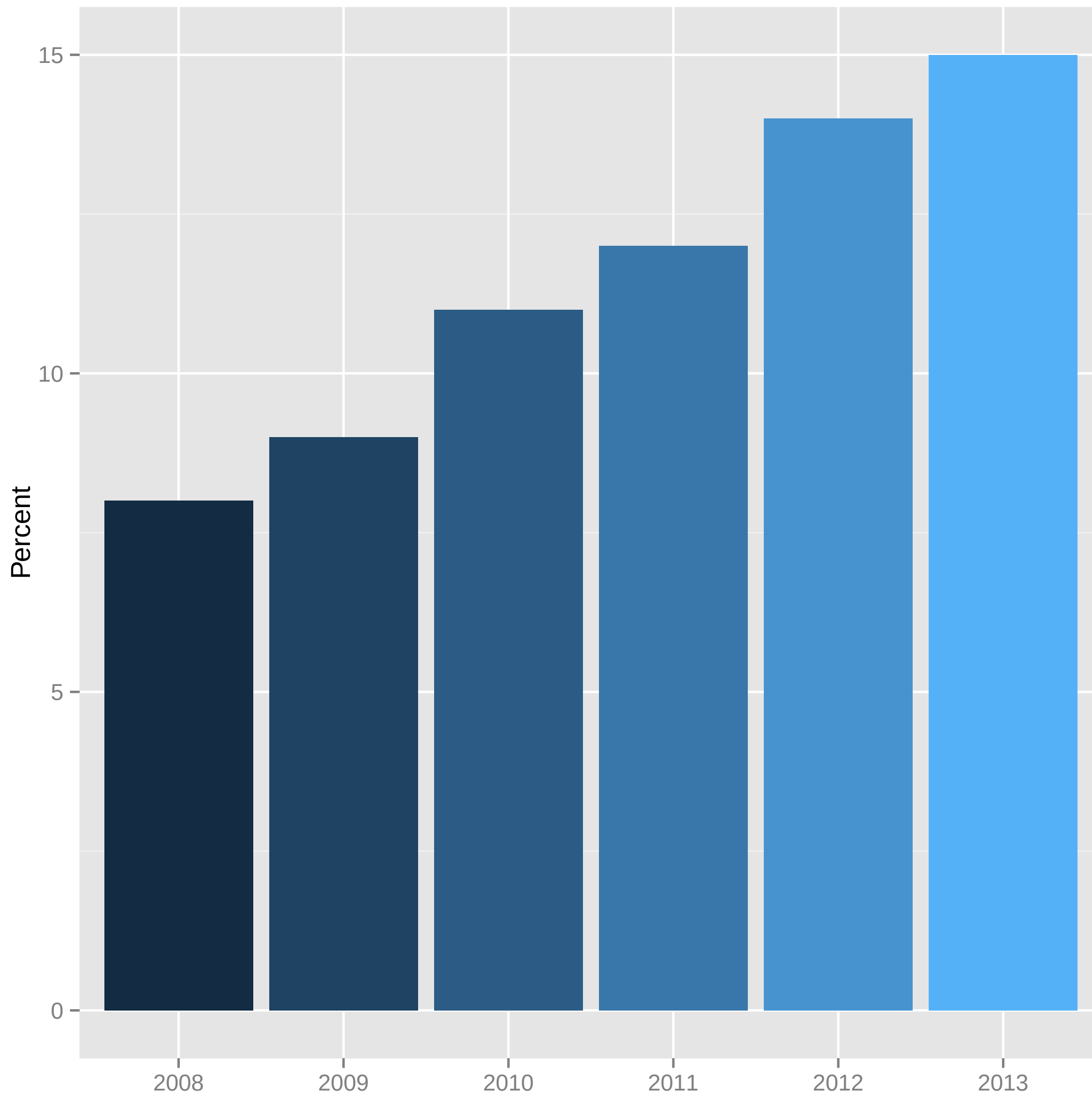


Figure 7.2: Alternative reinsurance capacity as a percentage of global property catastrophe reinsurance limit. Data from Guy Carpenter Capital Ideas Editor (2013) via Evans (2013).

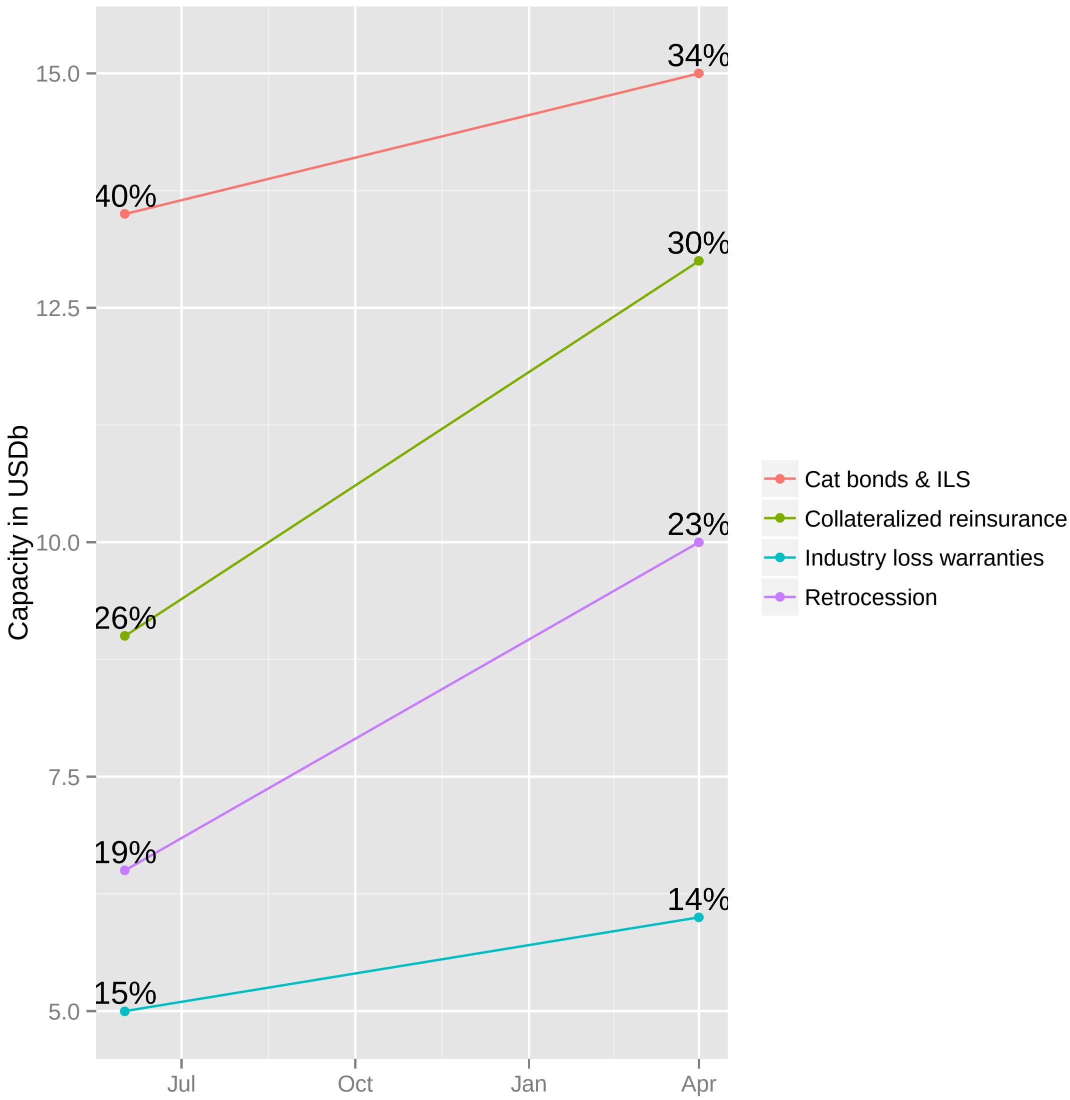


Figure 7.3: Alternative reinsurance capacity by type (in USB billion and percentages.) Data from Flandro and Mowery (2012) and Evans (2013).

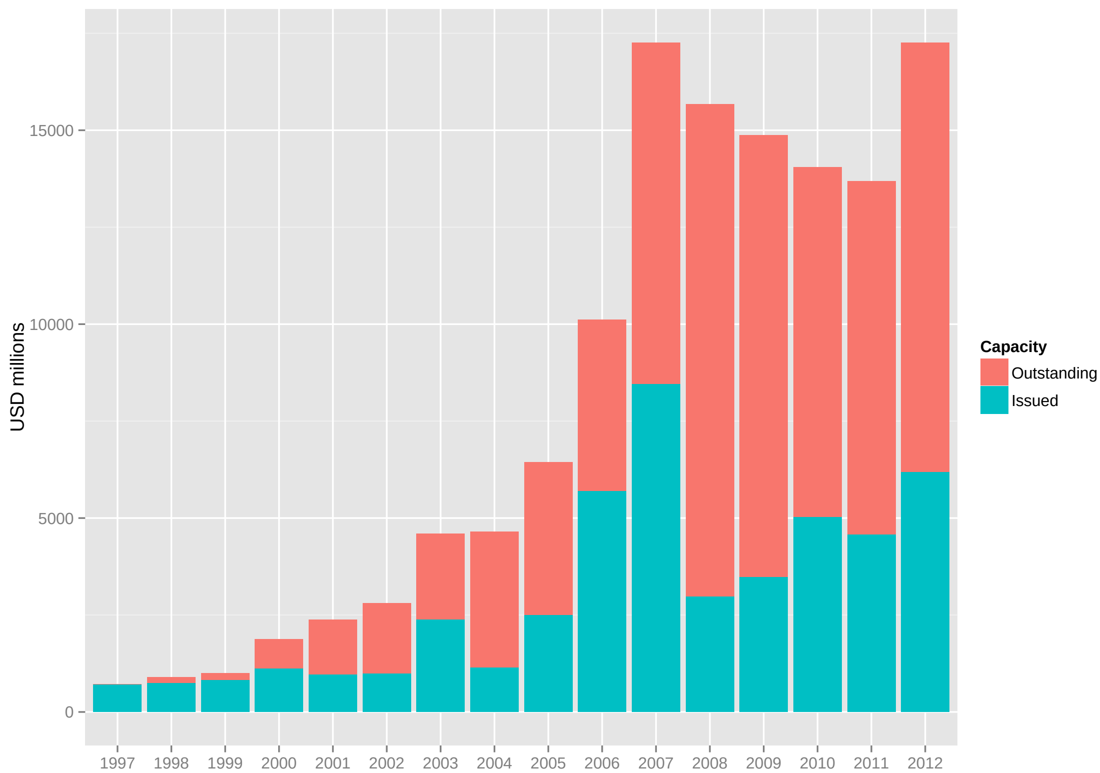


Figure 7.4: Total ILS outstanding as of July 2012. Data from Swiss Re Capital Markets and Bisping (2012).

that has defined reinsurance in recent decades. After a major loss, reinsurance prices have tended to skyrocket. Froot (1999) linked that cycle to shortfalls in the capital available for reinsurance.

CAT bonds may change that cycle by providing an avenue for firms in capital market firms (like hedge funds) to enter the reinsurance industry. In general, CAT bonds are fully collateralized, meaning that all the money needed to pay on the covered claims is set aside at the initial bond auction. Thanks to that arrangement, CAT bonds theoretically free of counter-party risk, allowing anyone to provide reinsurance coverage, even if they are not regulated as a reinsurance company. (Since the money in escrow is invested, there is the opportunity for poorly structured deals to introduce counter-party risk into CAT bond transactions. Following Lehman Brothers' collapse, CAT bonds that invested their collateral in Lehman-backed swaps meant to simulate safe investments were indeed threatened by counter-party default (Kurtov, 2010).) Capital markets have embraced CAT bonds in recent years, attracted by steady returns uncorrelated to the market.

Figure 7.5 shows how capital markets have gradually accepted catastrophic risk. Institutional investors have entered the market directly, and indirectly through their stakes in dedicated catastrophic risk funds. Gradually institutional investors, hedge funds, and dedicated ILS funds (whose ownership often overlaps with, for example pension funds placing capital in hedge funds that in turn have a stake in a dedicated ILS fund) have replaced traditional reinsurers in the ILS market. Recently, the private equity and buyout giant Kohlberg Kravis Roberts acquired a 25 percent stake in one of the two largest CAT bond investment managers, Nephila (Scism and Dezember, 2013). Chief executive officer of Berkshire Hathaway's General Re, Franklin "Tad" Montross, recently summed up that interest from institutional investors in CAT bonds (Buhayar and Mead, 2013):

> With interest rates being where they are, I don't think it's a surprise that a CAT bond with a yield of 350 or 500 basis points over LIBOR looks attractive. People are drooling for those.

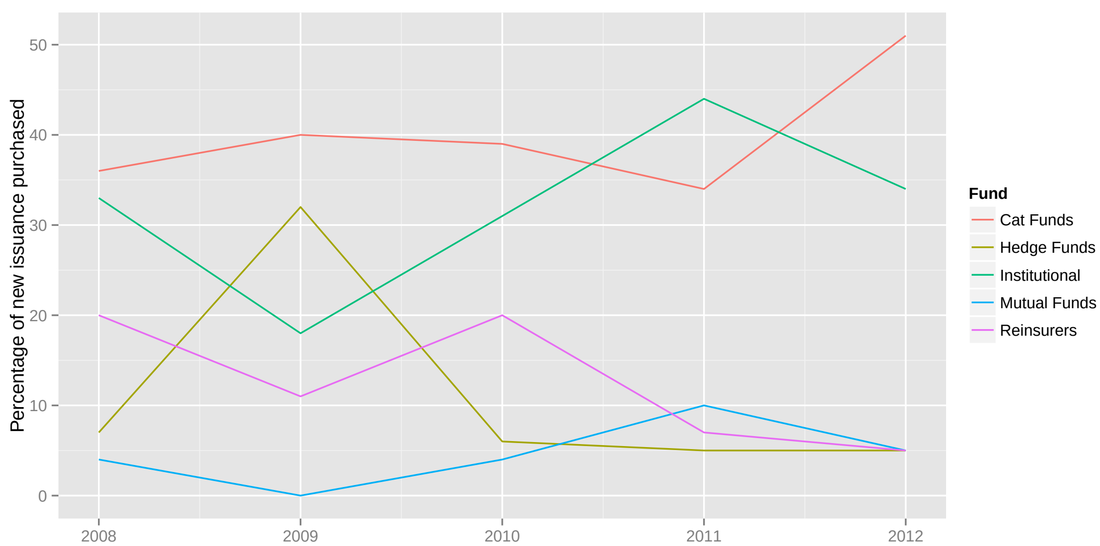


Figure 7.5: New CAT bond issuance purchase by investor type. Data from Schultz (2012).

Despite that influx of new capital, the use of CAT bonds continues to mirror reinsurance, particularly in the way they concentrate on *peak perils*. In figure 7.6 we see how the roughly USD 17 billion in outstanding CAT bond capacity was divided among perils. [2] The market remains highly concentrated in a few risks, particularly US hurricanes.

The industry's concentration of CAT bond capital in hurricane risk is also clear looking at the price differential between CAT bond coverage with and without US wind exposure. In 7.7, we see that investors are clearly willing to accept a lower return on risk that diversifies their portfolios. That gap has grown in recent years, perhaps due to the presence of dedicated funds who use portfolio-oriented risk management strategies.

[2] I provide my own estimate of peril by peril issuance in figure 3.11. That estimate makes some attempt to divide up *multi-peril* deals into their consituent parts, so the graph shows a much higher concentration in US hurricane risk than 7.6.

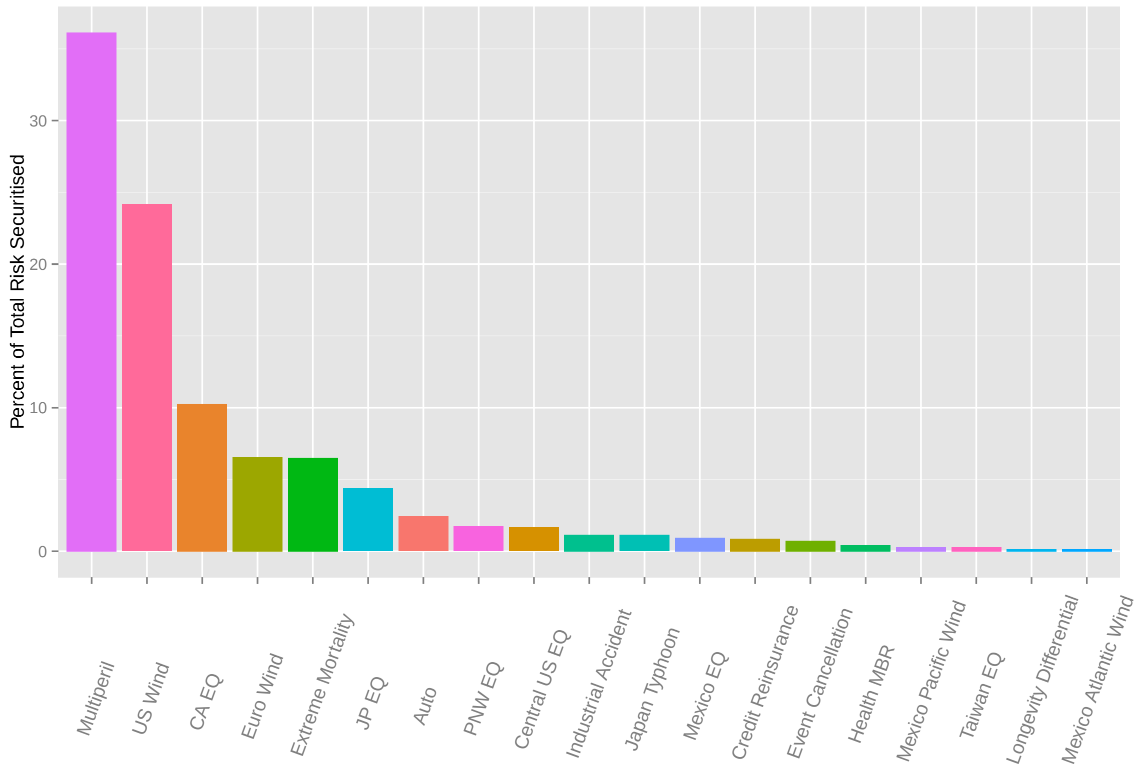


Figure 7.6: Perils by total risk securitized in millions as of May 2011. Data from Swiss Re (2011).

Initially, many believed that CAT bonds would lead to greater standardization within catastrophic risk markets. Markets finally had a means of rewarding insurance companies who were willing to accept some basis risk, because investors would gladly offer a lower price for relatively simple triggers with little moral hazard. In fact, the market has not systematically become standardized. One reason why insurers have accepted CAT bonds as a substitute for reinsurance is that investors have been willing to accept the same type of indemnity triggers common to traditional reinsurance. That trend toward indemnity triggers is clear in figure 7.8.

After an initial offering period, most CAT bond investors simply hold their notes to maturity. However, there is a relatively small *secondary* market in which investors rebalanced their portfolios and new entrants buy exposure when new issues are scarce. In 2011, that secondary market traded CAT bond notes of roughly USD one billion. Since some of those trades represent the same note changing hands multiple times, it is difficult to say how much of the total USD 17 billion in CAT bonds trade on the secondary market. Figure 7.9 shows secondary CAT bonds trading between 2010 and early 2012. It is difficult to draw conclusions from two years of data, but despite its lumpy trading within the sample, overall secondary trading volumes grew year on year from a volume of 792 in 2010 to 999 in 2011.

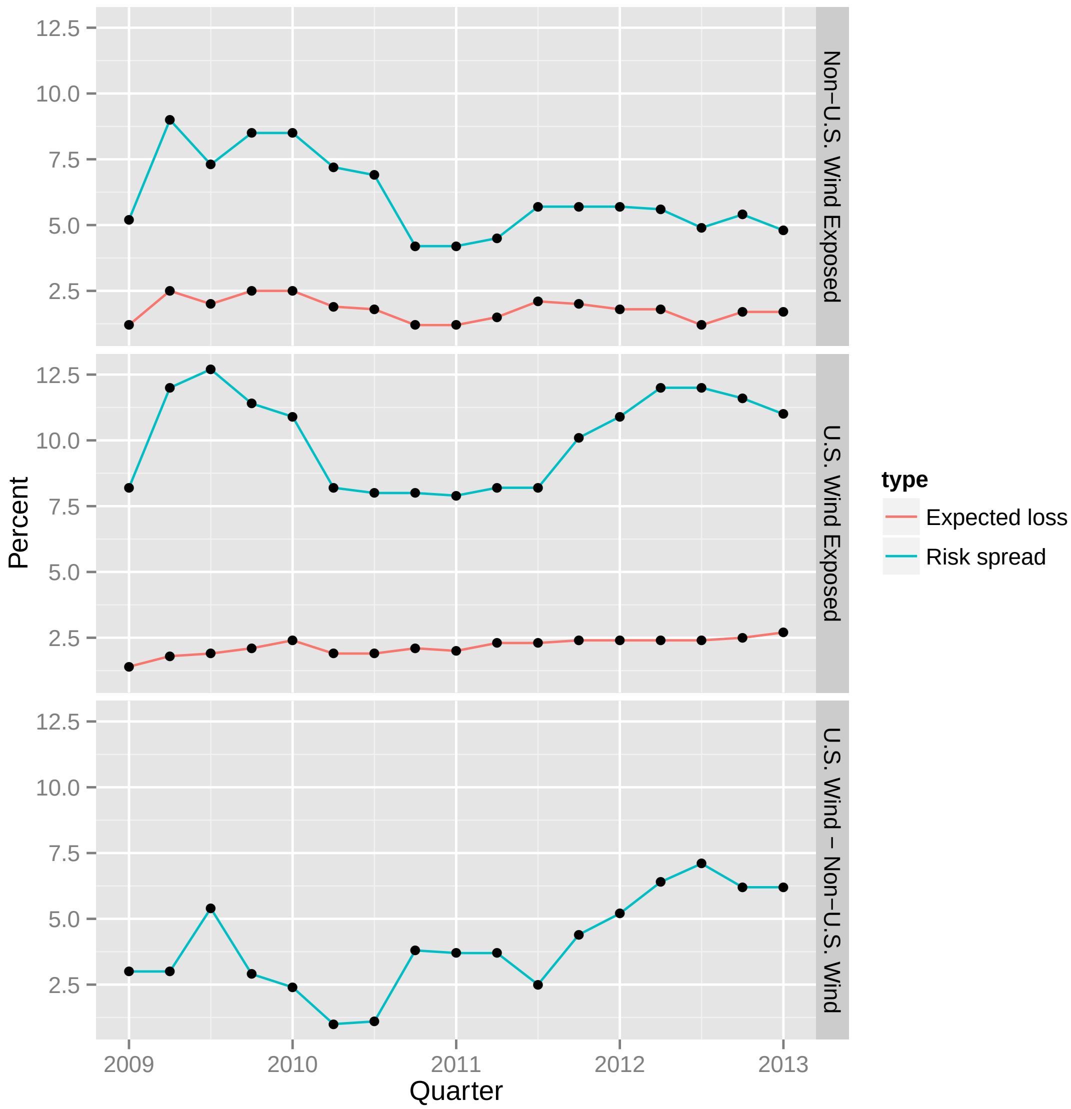


Figure 7.7: Willis Capital Markets & Advisory weighted average risk premium and expected loss on an index of CAT bonds over last 12 months. Data from Ursano (2013).

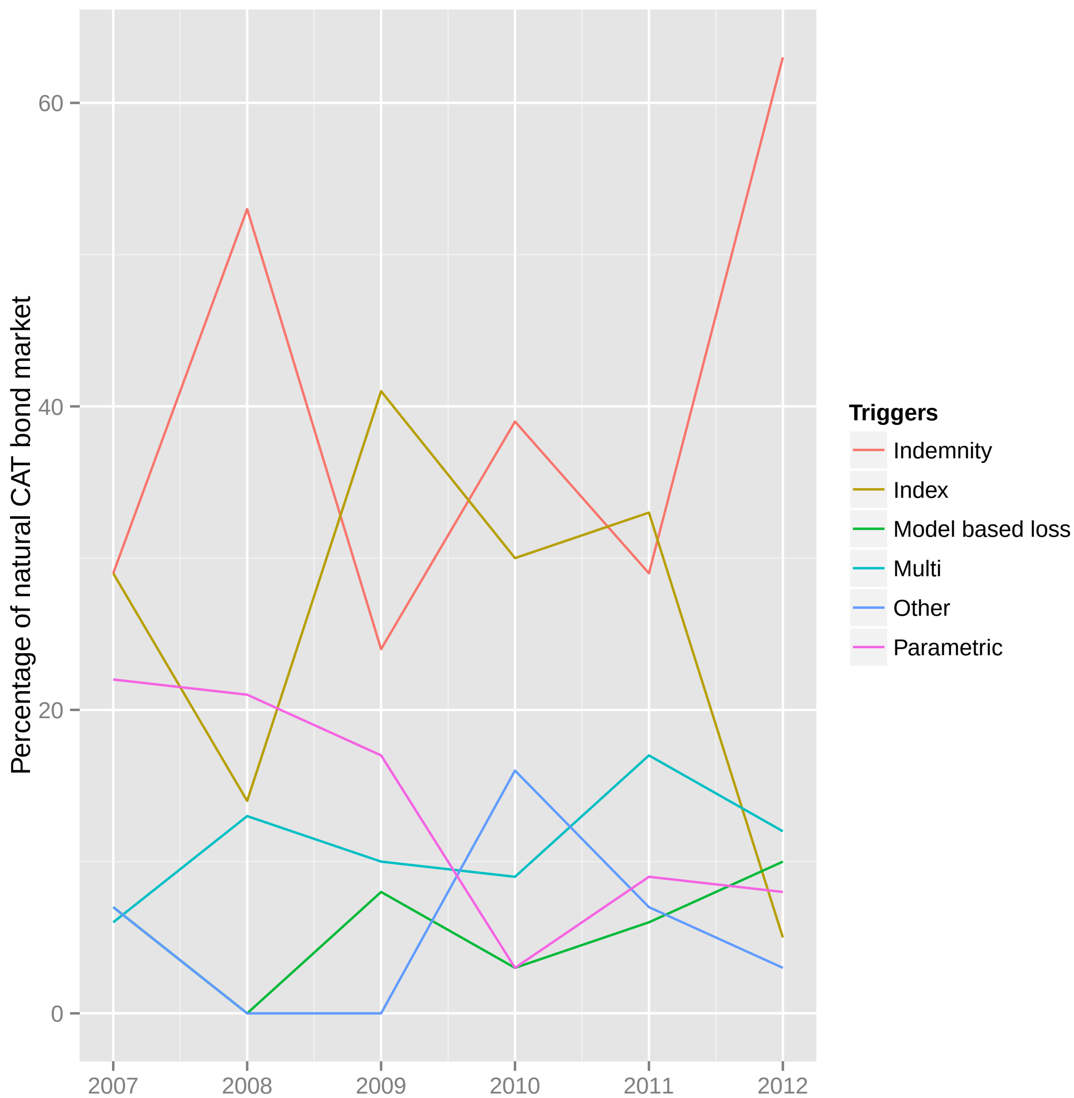


Figure 7.8: Natural catastrophe bonds by trigger type as of August 2012 (includes only natural catastrophe, excludes life, health, and sidecars.) Data from Millette (2012).

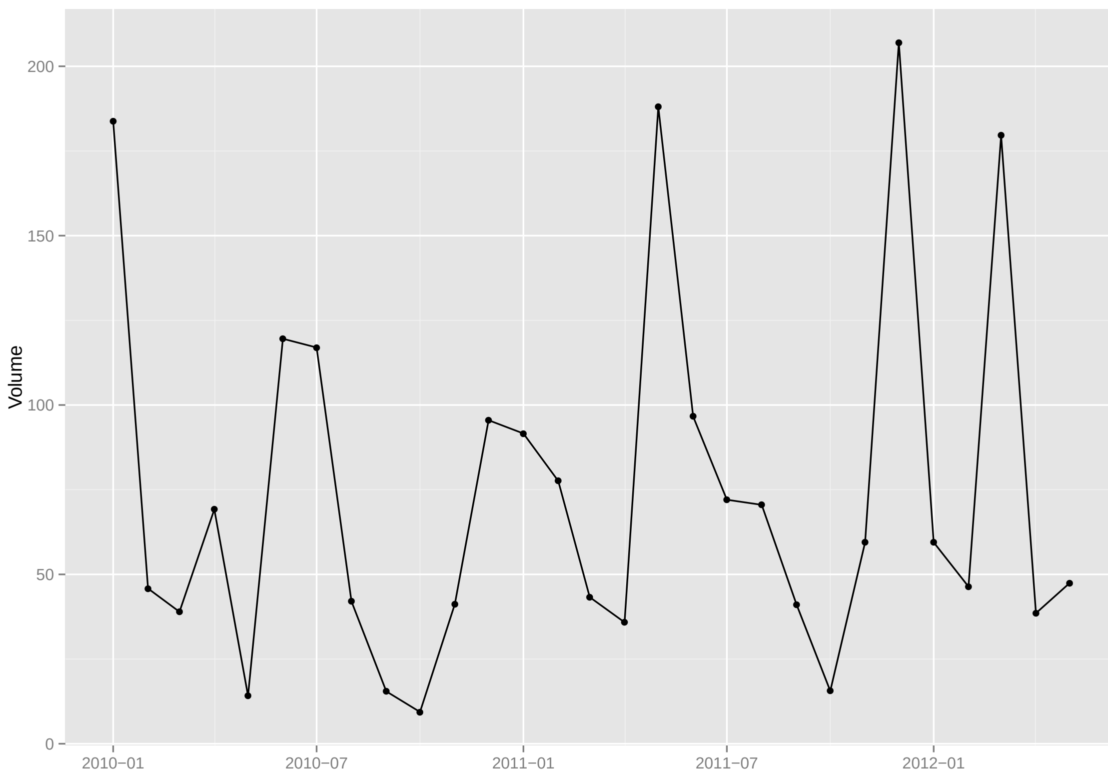


Figure 7.9: Secondary trading volume for ILS. Data from Swiss Re (2011).

7.2 Weather derivatives

Another market relevant to ENSO is that for weather derivatives. Weather derivatives involve payments contingent on an index of weather data such as the temperature or rainfall at a given weather station. The Weather Risk Management Association (WRMA), the main industry association for weather risk professionals, estimates that the total notional value of weather derivatives traded in 2011 at roughly USD 12 billion[3].

Figure 7.10 provides WRMA's estimates for the notional value traded based on press releases related to their semi-annual member survey (wrm, 2013). It shows that weather trading grew rapidly in the run-up to the 2007-2008 financial crisis, crashed, and has yet to recover to pre-crisis highs. Figure 7.11 tells the same story using volumes on the CME's weather derivatives contracts (futures, options, and cleared swaps) with the ten largest contracts by 2011 volume highlighted.[4]

Weather derivatives markets began in the late 1990s. According to Aquila Energy, one of the field's pioneers, El Niño's weather volatility played a central role in the

[3]That figure is not directly comparable to the USD 17 billion for CAT bonds, since it is the notional value traded, not the notional volume outstanding. In the parlance of capital markets the USD 17 billion for CAT bonds is open interest, while the USD 12 billion for weather derivatives is volume.

[4]The CME dominates the weather trading market.

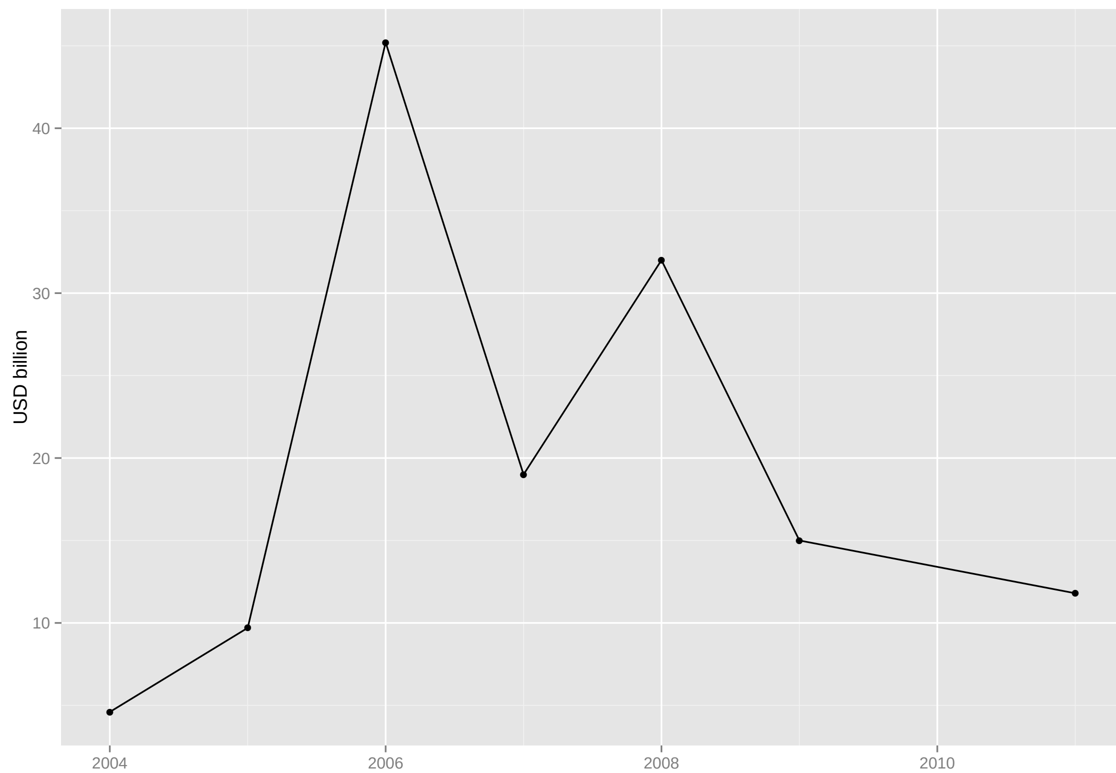


Figure 7.10: Notional trading volume of weather derivatives. Data form on wrm (2013).

market's development (Considine, 2000):

> The weather derivative market was jump started during the El Niño winter of 1997/1998, one of the strongest such events on record. This event was unique in terms of the publicity that it received in the American press. Many companies, faced with the possibility of significant earnings declines because of an unusually mild winter, decided to hedge their seasonal weather risk.

Given that historical connection, the close attention that today's weather traders pay to ENSO forecasts, and the indexed-nature of the phenomenon itself, it is easy to see why many of the industry professionals I interviewed suggested that ENSO markets should and would be traded as a weather derivative.

Two large energy firms, Koch Industries and Enron, pioneered the field of weather derivatives, offering investors specialized transactions based on weather station data in the late 1990s. A catastrophe risk specialist involved in those early transactions suggested in my interviews that one of these leading firms had special information on the history of the weather data used to settle the contracts. That information skewed the odds of payouts in the firm's favor.

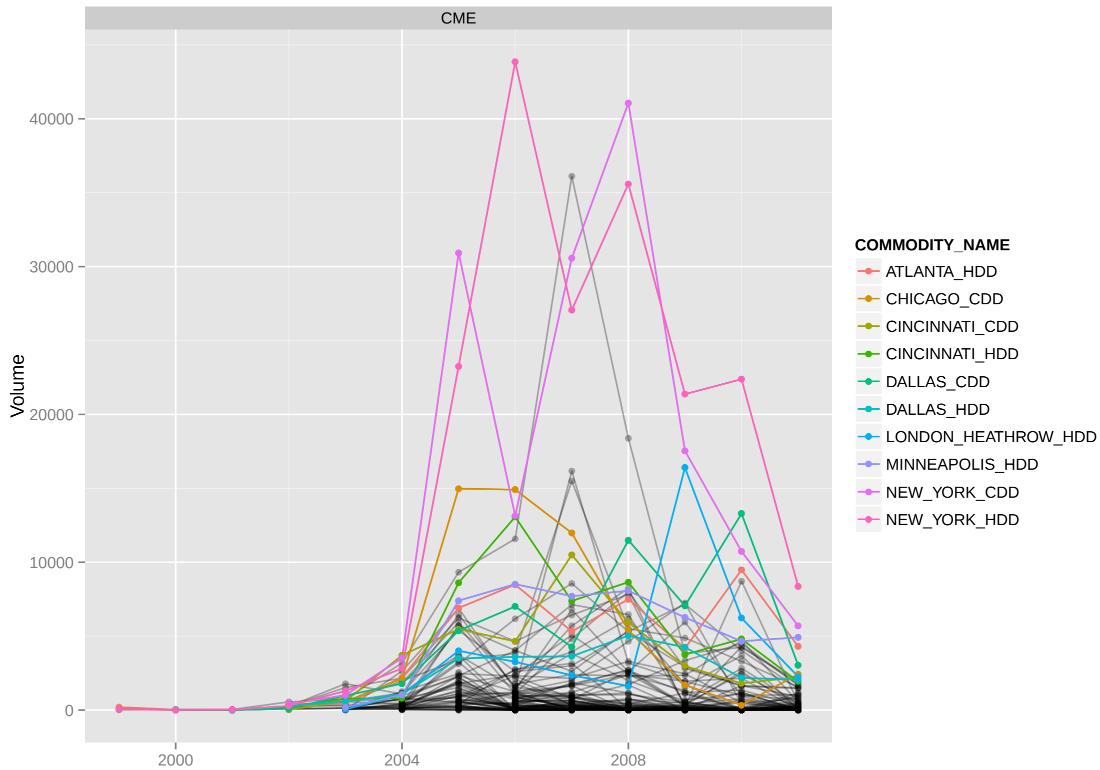


Figure 7.11: CME weather derivative trading volume by contract. The ten most popular contracts by 2011 trading volume are highlighted.

If indeed asymmetric information was a factor in early transactions, then investors caution was warranted. In 1999, both Koch and Enron contracted investment banks, Goldman Sachs and Merrill Lynch respectively, to help them move their creations to bond markets (Quinn, 1999). The Enron bond offer was aborted after it failed to attract sufficient investor interest, in part because prospective investors did not believe they had the expertise to trade weather competently (Quinn, 2000).

Enron's bankruptcy represented a major setback for weather market liquidity. Shortly before the firm's failure, some estimated that the firm represented as much as 30 percent of overall trading on weather markets (Springsteel, 1999). Indeed, multiple weather traders independently lamented that Enron's collapse set the market back "ten years," according one interview subject. Nevertheless, volume on the CME's weather contracts grew through the mid-2000s, as is clear in 7.11. Energy firms, particularly natural gas firms, continue to dominate trading to this day. As I discuss in chapter 8 few of those firms consider weather risk a growth market at the center of their strategic plan, the way Enron did (McLean and Elkind, 2004).

After the global financial crisis, weather derivatives volumes crashed (see figure 7.10.) Even including OTC trading, notional volumes are a fraction of their pre-crisis peak. That trend, combined with the divestment of large banks from commodity trading in general, and the abundance of natural gas (the commodity most closely linked to weather trading), particularly in the US, has led many large banks and hedge funds (including Morgan Stanley and Citadel) to shutter their weather desks in recent years (The Economist, 2013a) (The Economist, 2013c).

7.3 CAT derivatives

Distinct from weather, catastrophe derivatives offer a more complicated precedence for ENSO markets, one marked by multiple rounds of innovation that never managed to achieve sustainable on-exchange liquidity.

The first round of innovation predates both CAT bonds and weather derivatives. It was hosted by the Chicago Board of Trade, with reported volume between 1992 and 1994. Figure 7.12 shows volumes for those contracts. They settled on indexes of reinsurance industry losses. At the time, reinsurance professionals viewed those indexes with suspicion. However, in the intervening years many CAT bonds, reinsurance agreements, and industry loss warranties settled on similar indexes. At least one industry expert I interviewed believes that, given the familiarity of industry professionals with those indexes, the CBOT contracts would have stood a much better chance had they been first launched today.

As Sandor (2012) details, the index was not the only problem with those early contracts. In particular, the CBOT contracts launched as futures which, as I discussed in chapter 4 are a poor structure for catastrophic losses. (Although, they may be entirely appropriate for industries with very low basis risk and special index expertise.) Only after the futures struggled did the CBOT introduce options.

Exchange-traded catastrophe derivatives were reborn almost a decade later. The CME's suite of contracts were developed by the reinsurance brokerage Carvill and first offered in 2006. Most of the contracts settle on the Carvill Hurricane Index, a purely parametric measure of hurricane impacts over specific regions. The risk modeling firm EQECAT is in charge of calculating the index using NOAA data and is responsible for providing alternative data when NOAA figures are not available (Kurtov, 2010). As I mentioned in chapter 4, indicative prices on the contracts' marketing materials suggest a modest, but unstable pricing advantage for hedgers choosing these markets over reinsurance or ILS. Despite being offered on an exchange, most of the trading is bilateral either as block trades or OTC swaps. Also while the CME offers a range of structures including futures, my interviews indicate that virtually all trading trading to date has been in the form of binary options.

Figure 7.13 shows trading volumes for contracts in a competing suite launched on IFEX, an exchange associated with the Chicago Climate Exchange (CCX). IFEX catastrophe contracts follow the same pattern as the weather derivatives in figure 7.11, with a peak before the financial crisis, a crash, and a modest recovery for some contracts. Both the IFEX contracts and those launched in 2009 on EUREX, attempt to mimic ILWs, settling on an index of industry-level losses over specific regions (Kurtov, 2010).

Kurtov (2010) suggests that the total notional value of catastrophe derivatives and ILWs for property and casualty risk (i.e. excluding mortality or longevity) is between USD 5 and 10 billion. Estimates from reinsurance broker Guy Carpenter (figure 7.3

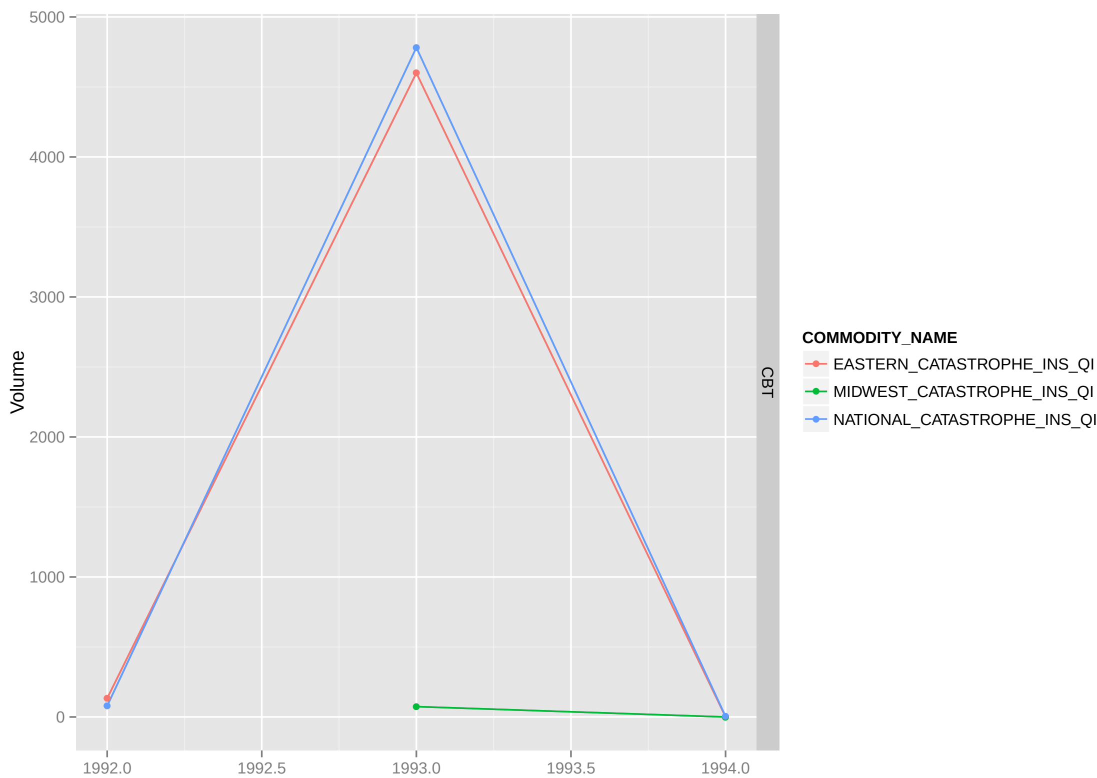


Figure 7.12: CBOT catastrophe derivative trading volume by contract.

and Manning (2012)) place ILWs' contribution between USD 5 and 6 billion. Only a few of the firms I interviewed actively use catastrophe derivatives, while most trade ILWs. Both the estimates and the anecdotal evidence from interviews suggest that catastrophe derivatives represent the smallest market discussed here.

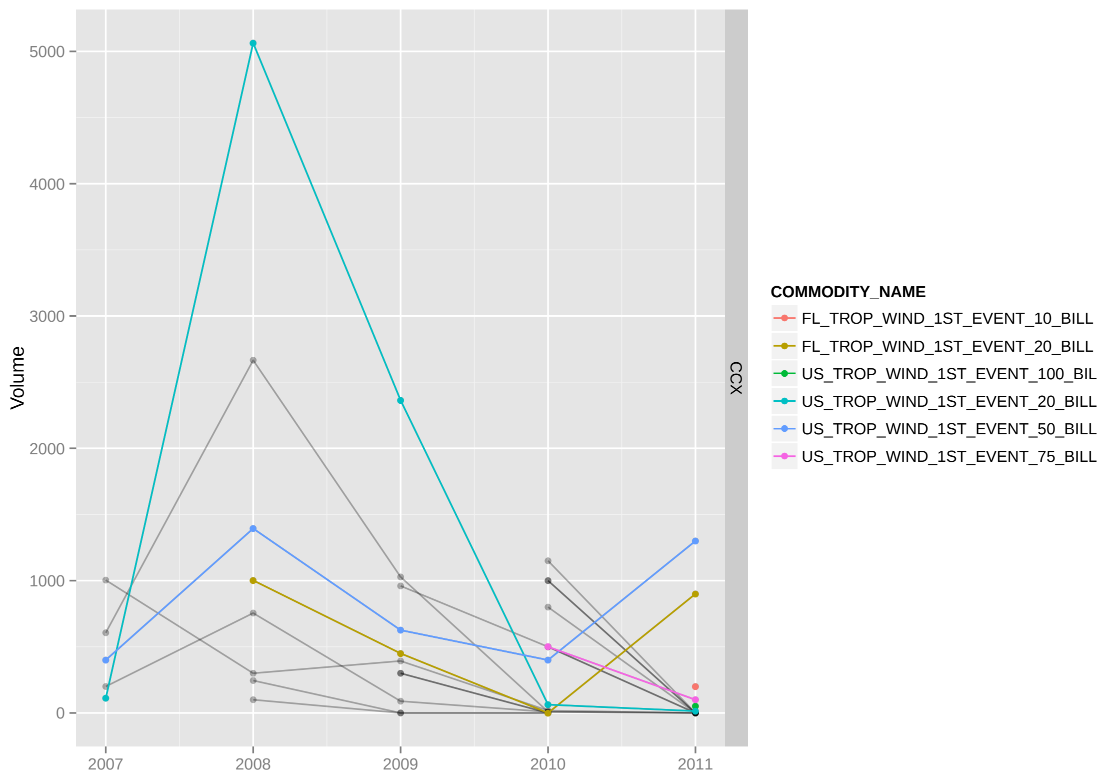


Figure 7.13: IFEX/CCX catastrophe derivative trading volumes by contract. The six contracts in the sample with positive 2011 trading volume are highlighted.

Chapter 8

Interviews With Risk Professionals

Communities of hedgers, speculators, and service providers ultimately determine the success or failure of any new market. So, for these last chapters (this chapter and the next), I interviewed over 35 firms and institutions from the ENSO risk community. In those interviews, I tested assumptions that arose out of the research in my previous chapters against the opinions of experts - likely ENSO hedgers, speculators, brokers, and service providers.

The results overturned many of the assumptions that lead me to favor exchange-traded futures and options for ENSO risk. But, they also highlight the opportunities for ILS markets to provide a low-risk alternative to exchange-traded futures and options. Those markets would catalyze trading activity in the near-term that could transition to exchanges. Based on this information, it is likely that CAT bonds offer the best chance for ENSO to reach sustainable levels of trading. Supplemented by a liquidity facility that provides options-like hedges to smaller businesses, CAT bonds would adequately address most of the social concerns presented in chapter 5.

This chapter includes:

- a road map for the launch of ENSO markets based on qualitative interviews with likely ENSO hedgers, speculators, brokers, and service providers; and
- the interview results that informed that road map, organized by firm/institution type.

To the extent possible, I've tried to arrange the tested assumptions in order of their importance to the ultimate shape of ENSO markets.

8.1 Road map to launch ENSO markets

Drawing heavily from expert interviews, the following is one possible road map for ENSO markets. This road map covers the likely hedgers exchanging risk, the speculators making up for any imbalances in hedging interest, the brokers consummating those deals, and the service providers underwriting all that activity with their data and analysis. It also covers the market structure that is most likely to cover the greatest volume of trading activity in the short term.

Market structure

With a few exceptions, interview subjects suggested a greater willingness to invest in and transact on ILS markets (in the form of CAT bonds) than on exchange-traded futures and options. Many agreed with the suggestion that ENSO's natural home is on exchange markets, given the nature of the risk. However, most speculators and brokers were clear that, while not categorically opposed to exchange-traded ENSO markets, they and their colleagues prefer ENSO-based ILS because:

- ILS allow speculators to avoid costly up-front investment in dedicated expertise required by exchange-traded markets; and,

- ILS allow brokers to capture a greater return on their investment in the educational effort necessary to attract new hedgers to a market. Brokerage firms are the only firms likely to make any such investments.

While hedgers do not have the same strong preference for ILS, nor were they committed to exchange-traded markets. In existing markets, even when they have the option of trading weather or catastrophe risk on-exchange, they generally elect to use OTC or block trades. As they already prefer bilateral negotiation on their trades, likely ENSO hedgers are indifferent to one of the key advantages of exchange-traded derivatives.

A brokerage associated with the CME's exchange-traded hurricane derivatives reinforced this story, suggesting that ILS would offer better short-term opportunities for liquidity than exchange-traded markets. That brokerage has made substantial investments in exchange-trading and is firmly committed in principle to moving catastrophic risk on-exchange. Consequently, their opinion was particularly influential.

Hedging

If ENSO markets launch as CAT bonds, who will be the first hedgers on those markets?

In rough descending order of their importance to the prospects for active ENSO-based CAT bond markets, I consider the following firm-types to be early hedge adopters:

1. Peruvian fishing companies - My interviews suggest that large fisheries in Peru will likely be the single most important source of early hedging interest on ENSO markets. The risk is an existential threat to their industry. Importantly, some firms in the industry also have the internal capacity to quantify that risk and manage it on traded markets.

2. International agribusinesses - Despite their scope and vertical integration, international agribusinesses have geographically concentrated supply chain risk that will push them into experimenting with new ENSO markets as well, regardless of the form they take (ILS, derivatives, etc.). Those firms are comfortable experimenting in new markets and ENSO is unlikely to be an exception. However, it is difficult to assess the prerequisites for them to scale into consistent, large positions.

   Even if their initial positions are small, I consider them second only to fisheries in their importance to new ENSO markets because other hedgers consider these firms bellwethers for new risk management techniques. Without some support from large agribusinesses, ENSO markets will likely remain at low liquidity.

3. US energy firms - US energy firms' experiments with ENSO markets will likely mirror those of large agribusinesses. The firms would gladly take exploratory positions in ENSO risk. The size of those initial positions would vary greatly, depending on the support they had from trusted weather experts. In particular, their first El Niño trades might focus on hedging summer electricity price spikes in Texas and California. If, after those initial trades, they saw no specific reasons to doubt the integrity of the index and there was good momentum in attracting new hedging interest, they would increase their trade sizes.

   Given that wait and see attitude, ENSO exchange markets appear likely to attract anemic volumes unless they build a coalition of progressive firms that agree to dedicate the resources needed to generate substantial intra-industry volume on day 1. Multiple such consortia have formed to compete for the business created by the *futurization of swaps* in response to Dodd-Frank regulations (Rennison, 2013b). (For overviews of the futurization process and its impacts on derivatives markets see Duffie (2013), Litan (2013), and Parsons and Mello (2013).)

4. Australian power transmission firms - Reinsurance rates in Australia are very low. That competitive dynamic will likely crowd-out a great deal of latent ENSO hedging. However, some power transmission firms are deeply concerned with bushfires that have a strong link to ENSO. In fact, they have already incurred legal liabilities related to that risk. Those liabilities have jeopardized their future access to low-cost (or perhaps any) reinsurance coverage. As parastatals, they are required to actively manage their liabilities to protect taxpayers from losses. That leaves them motivated hedgers in search of new risk management tools - ideal early adopters of formal El Niño hedging.

5. Peruvian banks - Peru's banking sector lacks expertise in hedging. However, reasearch by Dr. Benjamin Collier[1] suggests that they have enough exposure to El Niño risk to justify their own CAT bond issue. Converting that interest into hedging activity will require substantial educational support, which is why I consider the sector less important to the prospects for ENSO risk than other less vulnerable firms.

6. Australian hydro-power producers - Australian power generators with hydro-power installations offer another promising source of hedging interest. Like the multinational agribusinesses I spoke to, hydro-power companies would strongly consider ENSO trading. Given careful and sustained support from brokers, they could eventually be important sources of hedging interest. However, basis risk may limit their contribution to ENSO markets. Rainfall in Eastern Australia and Tasmania show a strong correlation to the ENSO cycle. But hydro-producers are more focused on the interaction of rainfall with water re-

[1] Then with GlobalAgRisk/the University of Kentucky, now doing post-doctoral research at University of Pennsylvania's Wharton School.

source management, so ENSO hedges have higher basis risk for hydro-producers than might otherwise be expected.

7. Peruvian agribusiness, energy, and mining - A small subset of at risk firms in Peru have the sophisticated risk management, scale, and interest necessary to participate in formal hedging, given attractive pricing. But that interest will be vary greatly from firm to firm and project to project. I do not believe that I can accurately estimate the aggregate size of hedging interest from these individual projects.

8. Australian agribusiness, mining and tourism - In addition to the utility companies and hydro-power generators mentioned above, there may be acute demand for ENSO risk management in Australia linked to specific projects in coal mining, tourism, and agricultural lending.

9. Conventional reinsurance and ILS funds - Firms holding reinsurance related risk are unlikely to provide much hedging interest to ENSO markets in the near term despite the phenomenon's negative correlation between ENSO and hurricanes. The basis risk is too high in the tail loss scenarios that drive capital reserving.

This profile of early hedging activity is skewed in favor of El Niño hedging. That means that speculators will balance the market, regardless of its form.

Market access

If ENSO risk initially trades as CAT bonds, and access to CAT bond markets are generally limited to large sophisticated firms (like those discussed in the hedging subsection above), what hope is there that ENSO markets can offer widespread access to well-priced hedges and disseminate important forecast information about extreme ENSO events?

John Seo of Fermat Capital suggested one attractive compromise that could link small, or socially important, hedgers to ILS markets. After ILS brokers have consummated the first large El Niño/La Niña trades, a development institution (probably the IFC, the World Bank's arm dedicated to financing individual socially responsible businesses) could use the prices of those bonds in the secondary market to offer option-like coverage to the smaller hedgers who could not easily participate in the CAT bond issue. The development institution, interested in the emergence of stable, commercially viable climate change mitigation tools, could offer to aggregate hedging interest for a small fee using a liquidity fund.

The fund would price an option chain using prices implied by secondary CAT bond trading. Available trades would be capped both in terms of the the nominal value per hedge and the total nominal value per hedger. As the facility sold protection, it could hedge the risk in secondary markets and sell on any basis risk between their portfolio and the secondary markets to ILS funds. Alternatively, it could just sell the risk on the policies directly to ILS funds who would be happy to quote prices on a basket of small options trades but not one-off transactions. By passing on that risk, the facility could maintain a risk neutral portfolio.

If the IFC wanted to subsidize risk management for socially important firms and institutions, this facility would offer an efficient means of doing so. However, the facility could price all the premiums at market rates. By pricing the options fairly, it would operate at no net cost it its host institution.

This would allow large sophisticated hedgers to transact directly in CAT bond markets and still provide smaller hedgers flexible, fair access to option-like protection. It would also advance the eventual cause of a stable, self-sufficient ENSO options market, allowing investors to get a sense of the overall market size while skirting the fixed cost problem of a direct launch. Eventually, once investors were ready, that pseudo-options facility would be discontinued and all the hedging would be shifted to a genuine exchange along with the ILS trading that underlies the facility.

The World Bank already has two similar programs. The Caribbean Catastrophe Risk Insurance Facility allows Caribbean countries to jointly purchase hurricane and earthquake reinsurance coverage(Caribbean Catastrophe Risk Insurance Facility (CCRIF), 2013). More recently the World Bank launched a similar facility aimed at tsunami risk in the Pacific Islands(Group, 2013). Those facilities aggregate demand from hedgers (national governments) who might not otherwise have access to reinsurance markets on favorable terms. These facilities are also conduits for direct subsidies to poor countries. The World Bank pays the insurance premiums of some participating countries, both through soft loans and, as in the case of Haiti, grants (Stichter and Young, 2010).

Speculation

Launching ENSO risk in the form of a CAT bonds assures reinsurance risk professionals a role in the new market. The markets for new CAT bond issuance is one-sided (see chapter 5), with specialized financial firms (see figure 7.3) taking the risk of hedgers in exchange for speculative returns.

The firm types most likely to participate in that issuance in descending order are:

1. ILS funds - ILS funds would be very excited to trade CAT bonds on ENSO risk in the near future. They are highly skeptical of exchange-traded options for their firms and believe that, in the current pricing environment, hedgers would enjoy little if any price advantage from options relative to CAT bonds.

2. Dedicated weather trading desks at hedge funds (or within ILS funds) - These groups would be unequivocally supportive of exchange traded El Niño/La Niña derivatives although they noted that trading volumes throughout the weather markets had fallen in recent years (confirming the story told by figures 7.10 and 7.11).

   While they support exchange-traded markets, the weather trading firms I interviewed, are also entirely comfortable transacting on bilateral markets.[2] OTC transactions account for the majority of their overall deal flow and most of

[2]There was one exception - a firm whose mandate is restricted to trading cleared weather products.

their on-exchange trades are bilaterally negotiated blocks. Hence, they would be willing and able to provide speculative capital to ENSO hedgers, regardless of the form of those hedges.

Some large ILS funds have dedicated weather-trading groups. Those I interviewed suggested that they would classify ENSO risk as weather rather than catastrophe, assuming that it was traded as a derivative. It remains an open question where ENSO CAT bonds would be housed within these organizations - on the weather desks that trade more actively and use ENSO SSTs to guide that trading, or in their parent ILS funds that mange buy-and-hold portfolios of tail risk.

3. Conventional reinsurance groups - My interviews suggest that reinsurers will not be at the vanguard of speculative trading of ENSO risk. A few progressive reinsurance firms will participate in any market. Firms with managers who previously worked at ILS funds are most likely to fall in this category. That subset of firms will participate enthusiastically if the risk is offered as a CAT bond less so if it is launched as a derivative. But in general, the sector has a well-defined business strategy and actively traded risk is, optimistically, on the periphery of that strategy.

In general I am confident that these three groups of speculators will be eager to manage whatever volume of ENSO risk they can access via CAT bond markets.

Brokerage

More than any other group of interviewees, brokers were emphatic that ENSO should initially launch as CAT bonds rather than exchange-traded futures and options. Before interviewing brokers I expected this reaction, given that they have an interest in remaining the primary avenue controlling the follow of information between hedgers and speculators, and exchange-traded risk-management products would offer fewer opportunities for asymmetric information.

However, I was surprised to learn that in fact many brokerages, or specialized units within large brokerages, had previously invested in projects intended to move reinsurance risk onto exchanges. Those brokerages' inclination toward CAT bonds was born of experience. Based on their past projects, they believed that:

- Brokerages are the only firms within the catastrophic risk industry that consistently invest in the education of clients on new risk management techniques. Even if that investment is less then necessary to capitalize on many solid ideas, it is the only investment available within the industry.

- Brokers as a whole have less incentive to make that investment if ENSO markets launch as futures and options because:

    - Futures and options offer less first mover advantage to innovative firms;

- Brokers find it difficult to convince hedgers to use traded markets without existing liquidity. Meanwhile, those hedgers have no expectation of liquidity on bespoke CAT bond transactions;

- Some brokerages with the expertise to catalyze ENSO trades simply do not deal in derivatives. In fact, they may consider them competition for ongoing brokerage activities.

But not all brokerages will support ENSO risk enthusiastically, even in the form of a CAT bond. The central pillar of support will come from the subset of capital markets groups within large brokerages that have driven past innovation in CAT bonds. Even among the handful of capital markets groups that might promote ENSO CAT bonds, there is wide range of institutional capacity and willingness to promote innovative deals. Some capital markets groups may consider ENSO CAT bonds beyond their core competency.

Despite general skepticism about the country's competitive reinsurance environment, I also found that traditional reinsurance brokers who were particularly interested in extending ENSO coverage to Australia. Their enthusiasm stems from their familiarity with specific opportunities to sell El Niño/La Niña coverage.

Service provision

ENSO CAT bonds will enjoy strong support from ILS funds and the capital markets groups at some brokerages. But those key constituents will need help from climate researchers and risk modelers to provide trusted data and risk analysis.

Based on my conversations with catastrophe risk modelers, I believe that it is quite likely that these firms will provide branded ENSO analysis for ENSO CAT bonds. Given that the firms that license their risk models deal overwhelmingly in reinsurance and CAT bonds, they also favor bonds over derivatives for ENSO risk.

To the extent that ENSO CAT bond risk is managed by weather trading groups, they will look to a different set of service providers specializing in weather. Those firms already closely monitor the ENSO cycle, so I do not believe that it will be difficult to convince them to augment their existing analytical products with information specific to ENSO trading.

Finally, climate scientists, specifically those at NMS are enthusiastic supporters of ENSO markets in general. The scientists I interviewed were open to changing their operating procedures to support markets, including new safeguards to ensure that new ENSO data are released at one time to the public. However, NMS are unlikely to provide actual settlement indexes for ENSO CAT bonds, given the bureaucratic hurdles in front of public-private partnerships.

While it would be ideal to see revenues from CAT bond settlement indexes going back to NMS to support basic research, if they are unwilling or unable to collect those revenues, there are a host of other firms who would be willing to step into that role, including weather data firms, catastrophe risk modelers, or financial firms specializing in index provision.

8.2 Hedger interviews: Peruvian fishing

Peru hosts El Niño's most immediate and devastating effects (see chapter 3). Consequently, the country must be at the center of any future ENSO risk market. Even if it is not the largest source of economic risk, it is home to the world's most motivated ENSO risk hedgers and some of its most capable speculators.

Within Peru, the single most important source of hedging interest will likely be the fishing sector. Fishing in Peru is:

1. a large industry,
2. with direct vulnerability,
3. concentrated in the hands of domestic firms,
4. often with world-class CFOs and climate expertise.

Peru fishing industry is large both as a percent of the global total and in absolute dollar terms. The country accounts for roughly 10 percent of the global fish catch (Evans and Tveteras, 2011). Recent estimates place the revenue from Peruvian fishmeal at USD 1.8 billion annually (Reuters América Latina Newswire, 2013).

El Niño risk and Peruvian fisheries

Peru's fisheries are some of the most productive in the world precisely because they sit at the end of the current system at the heart of the El Niño/La Niña cycle. In normal years, cold, nutrient rich water rises from the floor of the Pacific, just off the coast of Peru. This water is the basis for a vibrant marine ecosystem that sustains a productive fishery. In particular, the system hosts the world's largest anchovy population. Anchovies are the main precursor to fishmeal and fish oil, both of which are key components of many livestock and aquaculture feeds. They represent 86 percent of the country's catch by volume (Evans and Tveteras, 2011). So, Peruvian fishing industry's profitability is fundamentally tied to anchovies. Anchovies, in turn, are particularly sensitive to the ENSO cycle. That means that Peruvian fishing company's profits are tightly linked to the ENSO cycle.

In El Niño years, that upwelling of cold water ebbs and shifts further into the Pacific, interrupting the ecosystem that is so important to fishery companies. Anchovies migrate to cooler waters and spawn at depressed rates. That means that anchovies are not only scare in El Niño years, but their populations are dramatically lower in the years following an event (Barber and Chavez, 1983).

Perhaps more importantly, El Niño creates a incentive problem among fishing companies that exaggerates the impacts of the climate phenomenon (Aranda, 2009). Modern fishing is capital intensive. It requires boats and processing plants, generally financed through debt. However, high levels of debt create serious cash flow problems for fishing companies. While industry revenues are highly vulnerable and subject to catastrophic drops in El Niño years, debt servicing is a fixed cost that is hard to avoid in case of a disaster. Consequently, companies that have historically over-fished even in normal years have been particularly disrespectful of ecosystem dynamics in El Niño years, when stocks are most vulnerable.

This dynamic led the industry as a whole into bankruptcy and nationalization after the 1972/73 El Niño (Glantz, 1979). The industry was gradually released back into private hands over the coming decades, but it was not until after the 1997/1998 El Niño that the modern fishing sector emerged, with the government allowing private ownership of industrial scale vessels (Aranda, 2009). Consequently, fishery companies have highly variable institutional memory of the devastating impacts of El Niño, with some firms lacking any top management who were working in the industry in 1997/1998.

Peruvian fisheries management

To prevent a repeat of the 1970s, the Peruvian government has experimented with many fisheries management systems. The current *Individual Vessel Quota* system launched in 2009 effectively allocates a set percentage of the country's annual industrial catch to individual firms with the overall catch set by the government's oceanographic institute, IMPARPE. Some portion of that allocated catch is tradeable, making the system similar to the *cap and trade* system used for carbon emission trading in the EU. Estimating a sustainable annual catch requires complex modeling and extensive sampling.

The Individual Vessel Quota system has increased industry profitability. That in turn has fostered optimism about the industry's future, with neutral academic observers suggesting that the system has altogether ended the incentive problems that lead to past population crashes (Tveteras, Paredes, and Pena-Torres, 2011). We heard that sentiment echoed in meeting with some firms. Given that all of the largest historical crashes and times of most severe incentive incompatibility were catastrophic El Niños, it is very difficult to take that claim seriously. Indeed, to the extent that such "this time is different" thinking leads firms to increase their reliance on debt or ignore risk management, it may deepen the severity of the next crash.

It is difficult to estimate what percentage of the industry's USD 1.8 billion in revenues are lost in large El Niño events, because the current firms were too young to face the 1997/1998 El Niño. As an upper bound, we can look at the 1997/1998 El Niño and its impacts on anchovy catch. In the years prior to that event, Peru's annual catch was in the range of 7 million tons annually. In 1998, that dropped to roughly 1 million tons. Making the simplifying assumption that all industry revenue comes from anchovies, a large El Niño will cause revenue shortfall of roughly 85 percent or USD 1.53 billion.

Industrial fishing in Peru today

Following the government's decision to open fisheries to large private vessels, the sector consolidated quickly. Today, roughly a half dozen fishing companies, all associated with larger Peruvian conglomerates or international fishing companies, account for 70% of the country's overall pelagic fish production (Scotiabank, 2010):

- Tecnológica de Alimentos S.A.- TASA (parent conglomerate: Grupo Brescia)
- Corporación Pesquera Inca - COPEINCA (Grupo Dyer)
- Austral Group (Austevoll, Norwegian fishery company)
- Pesquera Hayduk (Grupo Martinez-Baraka)
- Pesquera Diamante (Grupo Ribaudo)
- Pesquera Exalmar (Grupo Matta)
- CFG Investment (China Fishery Group)
- Pesquera Centinela (Grupo Romero)

Despite aggressive (and sometimes successful) bids by foreign firms, the industry remains fundamentally domestic. Most of the firms listed with "Grupo" next to their name remain in the hands of industrial conglomerates with their roots in Peru and are managed out of Peru.

But international competition has attracted top talent to these firms. The CFOs we met with were shrewd negotiators, suggesting prices for insurance coverage at or below the pure risk. In many cases they had direct experience hedging interest rates and foreign currencies. Some had served as CFOs or top risk managers at large US firms.

Perhaps more importantly, they also had dedicated climate scientists who not only had the best available forecasts of sea surface temperatures across the Pacific, but also had the added advantage of data from their own fleets.

These climate teams provided the fisheries with information on the likelihood of sea surface temperature anomalies that was, in my opinion, as good or better than anything available to reinsurance companies. This created the possibility of adverse selection and is one reason why derivatives on El Niño/La Niña may be more appropriate for those fisheries than insurance. A dynamic price that moves to reflect the information available across all Peruvian fishing companies might provide a useful starting point for fishing companies and speculators to trade risk. Speculators will certainly remain suspicious of transactions with fishery companies that may have informational advantages. But a dynamic price can provide speculators with the assurance that competition is limiting the scope for information asymmetries.

This sophistication, both in climate analysis and in risk management, will allow fisheries to take outright bets on monthly SSTs. In so doing, they will provide information to the futures markets whose prices will be the basis for settling the options that will interest most hedgers. While these fishing firms would prefer to hedge with Niño 1.2 rather than 3.4, their climate teams will be comfortable forecasting either index.

Impressive climate staffs account for only a small percentage of the cost that Peruvian fisheries already incur because of El Niño. In addition to using mitigation strategies, like moving their fleet to different regions in the Pacific, fisheries maintain large cash reserves to service their debts in case of El Niño (Arias Schreiber, Niquen, and Bouchon, 2011). That strategy is costly because it requires companies to forgo current investment. By managing a portion of their El Niño risk through insurance, fisheries can invest more in their business today while benefiting from the same risk protection they would have received with a low-return strategy based exclusively on reserving. (See Introduction: Direct Climate Markets for a review of the academic literature documenting increased investment and firm value among firms that use formal risk management tools.)

The opportunity cost of savings

Of course, savings are a vital risk management tool. Insurance, derivatives, and related assets should never replace savings entirely. However, for companies with high internal rates of return, like those in the fishing industry, the opportunity cost of managing risk primarily through savings can be high. For a simple explanation of the benefits of insurance, compare the opportunity cost of using reserves to cover El Niño risk to the opportunity cost of buying insurance.

Here I define the opportunity cost of reserving as the difference between the return a firm would have earned on the money it sets aside for risk management, if instead they had invested it in their business at their internal rate of return (IRR), and the return they did earn by keeping the funds in a liquid asset at the risk-free rate (RFR). By that definition, opportunity cost of reserving USD 100 is:

$$\begin{gathered}(\text{IRR} - \text{RFR})* \\ \text{USD } 100 \\ = \text{Opportunity cost of reserving USD } 100 \\ \text{for an El Niño}\end{gathered} \tag{8.1}$$

Imagine that instead of reserving USD 100, a firm bought insurance coverage that would pay USD 100 dollars in the case of an El Niño. The firm pays a premium for that insurance and invests the rest at rate IRR. After paying that premium, the firm owns an insurance policy that has an expected value (E[insurance]). So the opportunity cost of buying insurance is the difference between IRR (what the firm would have earned if it had reinvested the premium) and the expected value of the insurance (as a percentage of the dollar paid in premium):

$$\begin{gathered}(\text{IRR} - \text{E[insurance]})* \\ \text{premium per USD 100in notional coverage} \\ = \text{Opportunity cost of buying insurance that pays USD } 100 \\ \text{in case of an El Niño}\end{gathered} \tag{8.2}$$

When choosing between insurance and savings, a firm worried exclusively about El Niño should buy insurance whenever the opportunity cost of reserving is higher than the opportunity cost of insuring, since the firms receives the same protection (USD 100 in case of a disaster) at a lower cost:

This is equivalent to the condition:

$$\begin{gathered}(\text{IRR} - \text{RFR}) \\ *\text{USD } 100 \\ > (\text{IRR} - \text{E[insurance]}) \\ *\text{premium per USD } 100 \\ \text{in notional coverage}\end{gathered} \tag{8.3}$$

Now apply a conservative calibration (calibration that likely errs favor of reserving) to see if the condition holds:

- IRR = 1.2 meaning that the firm targets an internal rate of return of 20 percent for its projects
- RFR = 1.05 meaning that the firm can achieve a return of 5 percent on liquid assets that are set aside as reserves
- E[insurance] = 0.5 meaning that the firm expects to collect USD 0.5 of insurance payout for every USD 1 paid in premium. (Most insurance has an expected value below 1 because the insured must pay the insurance company a small fee for managing their risk. In this case, we have set the fee high to provide a very conservative estimate of the opportunity cost of the insurance.)
- premium per USD1 in notional coverage = 0.06 meaning that the firm pays 6 for every 100 of risk protection

Given these values, the condition for buying insurance holds true:

$$(1.2 - 1.05) * 100 > (1.2 - 0.5) * 0.06 * 10015 > 4.2 \tag{8.4}$$

To be sure, this example makes some strong assumptions. No firm is exclusively interested in El Niño risk. But given the historical link between Peruvian fisheries and the ENSO cycle, that assumption is close enough to some managers' actual experience to demonstrate the idea that even with a modest internal rate of return, the implicit cost of reserving is relatively high and firms should consequently manage their most extreme El Niño risk through insurance, regardless of their risk aversion. Using insurance for some portion of a highly vulnerable firms' El Niño risk allows higher rates of safe investment.

8.3 Hedger interviews: International agribusiness

This section deals with large, vertically-integrated firms such as Cargill, Bunge, ADM, and Mars. They manage production and logistics for basic agricultural commodities (like soybeans) and industrial commodities related to agriculture. With some exceptions, their supply chains connect regions heavily influenced by ENSO to larger markets around the world. This means that they have substantial exposure to ENSO risk. Their scope also means that they are diversified, able to reshape their supply chains in response to climate anomalies. While they are natural hedgers, formal financial hedges will only be a part of a larger risk management scheme. Their interest in hedges will form around breakdowns and inefficiencies in their existing sophisticated risk management strategies.

ENSO risk and international agribusiness

The clearest indication of the importance of ENSO risk to these firms comes from the firms themselves. Bunge's 2010 and 2011 annual reports to shareholders suggest that ENSO risk does indeed overwhelm the firms' existing risk management plan.

Like both Cargill and ADM, Bunge relies heavily on southern Brazil and northern Argentina for agricultural production (particularly in soybeans and sugar) and weather in the region has important and immediate consequences for their profitability. Historically, the region experiences drought during La Niña and flood during El Niño (Grimm, Barros, and Doyle, 2000). In fact, according to some of the weather experts I spoke with, the region hosts one of the strongest connections to the ENSO cycle, outside of Peru and Australia.

The La Niña conditions of 2010 and 2011 were no exception to that historical pattern. Those years saw weather conditions that Bunge chairman and CEO Alberto Weisser called "hard to manage" in his 2010 letter to shareholders. The annual report details the specific losses catalyzed by La Niña's drought (Weisser, 2010):

> In sugar and bioenergy, results were adversely affected by dry weather in Brazil which reduced the volume and quality (sucrose content) of sugarcane available for milling, thus reducing the production of sugar and ethanol and lowering our capacity utilization which resulted in increased fixed cost absorption. The drought also damaged our sugarcane plantations, resulting in increased depletion of these assets, which will require replanting.

Interestingly, in the 2011, annual report, we see that Bunge has contingencies in their forward contracts that are meant to manage this type of risk. Sugar suppliers paid Bunge for failure to deliver on contractual shipments. Those contingencies triggered in 2010, paying Bunge "approximately USD 14 million" (Weisser, 2011). Even with that compensation and a rise in the market price of the sugar-related products they did produce from the region, the company still suffered.

One weather analyst specializing in natural gas and agribusiness suggested, the exposure of firms like Bunge goes beyond production and processing in the impacted region. The companies themselves sign forward contracts to deliver large shipment of soybeans (for example) to a specific port within a short window of time. Their global scope and world-class management allow them to do this. But weather may require them to rely on a less efficient supply chain, shipping from the US rather than Brazil. The differences between the cost of shipping from the more efficient and the less efficient supply chain may be substantial. Given the thin margins that they work on, it may in fact jeopardize their profitability.

While Argentina and Brazil will be the center of attention for agribusinesses looking to hedge ENSO risk[3], there are other regions where niche industries create even higher risk concentration. For example, Mars is susceptible to interruptions in the cocoa supply chain, concentrated in West African countries that also have substantial ENSO-related weather risk. That vulnerability is also likely to generate hedging interest. According to my interviews, it has already led Mars to hire a particularly large meteorology department that closely watches ENSO. That investment appears astute given the importance of ENSO forecasts to recent volatility in the world price of cocoa. (Agbroko, 2012).

Business models and concentrated geographic risk

Bunge's troubles with weather during the 2010/2011 La Niña suggest a paradox also impacting reinsurance companies. Both these large agribusinesses and large reinsurers have the scale to do things that other companies cannot - pay on large claims or deliver massive commodity shipments with great regularity. However, taking full advantage of that institutional capacity often means concentrating in high return activities with barriers to entry related to scale. Only large firms can insure hurricanes, so there is handsome compensation for the firms that do. Similarly in agribusiness, only large firms can effectively build their own logistics infrastructure in productive regions of the world that have chronically under-invested in infrastructure, like Brazil. The firms that make that investment and manage it well, can supply then entire world with basic commodities.

Both strategies create large contingent liabilities that may outweigh the diversification that their scale would otherwise allow. Reinsurer's capital resources allow them to diversify and insure risks, like the explosion of a space shuttle, that are entirely uncorrelated to their portfolio. But they never achieve great diversification because the largest and least elastic demand for that capacity is for perils like Florida hurricanes. The returns from those peak risks goad reinsurers into focusing their portfolios.

Similarly, large firms like Cargill, Bunge, and ADM can and do produce more products in more places around the world than other agribusinesses. But much of their logistical expertise ends up focused on moving soybeans from Brazil and Argentina to the rest of the world.

Chatting with the head risk manager at one of these firms, I asked if he enjoyed visiting Brazil. I assumed that the occasional trip to the tropics would be a welcome change of pace for someone otherwise bound to a skyscraper in a northern American city. His response told volumes about the company's risk exposure in Brazil. His work trips were too frequent, too long, and too intense to enjoy personally.

[3] One experienced weather trader indicated that Brazil's regulatory and tax treatment of hedging with derivatives was highly disadvantageous. He said that those concerns had scuppered past deals with large international agribusiness firms and would require attention for any ENSO hedges.

Risk management at large international agribusinesses

The head risk manager I interviewed at one large firm suggested that not only are these firms vulnerable to ENSO risk, but they would be comfortable managing that risk through trading. His firm rarely uses weather derivatives because they feel that the basis risk is too high, especially on rainfall indexes. He would however gladly consider ENSO contracts provided that he had analysis on the contract from a trusted weather advisory firm like MDA EarthSat.

With that information, he said that the research time required to enter their first trade was approximately 45 days. Presuming that initial research did not raise any serious concerns, his firm would enter very small trades simply to learn more about how a contract works. He said that they often felt they had little choice but to start with the smallest possible positions in new markets because the exchanges failed to provide valuable educational materials.

He was relatively open to any form of ENSO hedging although he preferred derivatives trades that were costless to open. While he believed his firm would be allowed to freely trade swaps as *end-users* under Dodd-Frank, he still wanted to avoid those contracts if possible.

8.4 Hedger interviews: US energy

In January and February of 2013, I spoke with weather experts at a handful of US power and energy firms. Those firms primarily trade electricity and natural gas. Electricity markets are more regional as the inability to store electricity creates geographic pockets of supply regulated on a state by state basis.

Weather and climate analysis in the US energy sector

Like the Peruvian fisheries, all the energy firms I talked with have dedicated meteorologists who closely follow ENSO forecasts. Those meteorologists indicated that summer temperature spikes in the western US (primarily Texas and California) were their primary ENSO-linked risks that they would like to see hedged. In particular, firms with physical assets would have a "powerful incentive" to hedge, according to one interview subject.

Occasionally meteorology teams at these firms help hedge using weather derivatives. More often, they simply provide their gas and electricity traders with daily updates on weather patterns. Those updates are considered so fundamental to trading decisions that they must be ready daily before traders arrive. Meteorological teams get to their offices in the early hours of the morning to prepare those reports.

Most gas and electricity traders prefer this weather information in its most simple format possible. One meteorologist described how his forecasts filtered down to traders as little red and green arrows indicating whether temperatures were forecast to rise or fall in specific areas on a map.

The meteorologists I interviewed were puzzled by this behavior, both at their firms and in the industry as a whole: Firms are paying for top-quality expertise. But they systematically water down the resolution of the resulting analysis. Why not simply use the high information directly in weather markets either for hedging or speculation?

Weather derivatives and the US energy sector

Energy firms could use their climate teams for speculative bets on weather, just as they do for speculative bets on energy prices. However, Chincarini (2011) (discussed in chapter 4 with tables reproduced in Appendix C: Miscellaneous) matches weather prices to actual outcomes on major exchange-traded weather indexes and finds remarkable price discovery, despite their low liquidity. Some of the markets studied did not offer either side of the trade a consistent premium. So, it is possible that energy firms do not believe that they can consistently profit from speculative trades.

The superficial answer for why the firms do not hedge more aggressively is that standardized weather markets involve too much basis risk. This was a common theme from all my interviews with firms engaged in weather trading. When firms hedge weather, they strongly prefer bespoke transactions, often structured as OTC swaps, to standardized weather indexes. But specialized agreements have low liquidity and increase the chance of information asymmetries, as discussed above in the context of the first weather derivatives trades. So basis risk forces firms into contracts that create a *market for lemons problem* (Akerlof, 1970).

While all the traders I talked with mentioned basis risk, they were also careful to point out that the power and energy industry's unwillingness to bring weather trading into their core business is, above all, a collective action problem. Many people at many firms would like to trade with one another, if only there were more people trading in these markets.

The work in chapter 6 tested path dependence for trading activity. If there were no path dependence and volumes followed a log-normal random walk, then all of the probabilities in that chapter's transition matrices would be roughly equivalent. But those probabilities vary greatly from one level of volume to another, herding contracts into liquidity buckets. This suggests that there is indeed some path dependency to trading, consistent with traders' beliefs.

Enron famously may have solved that collective action problem, if they had continued to operate. They aggressively sought to bring trades across a host of markets, including the weather derivatives they helped launch, onto their electronic platform. But that electronic platform was unlike its contemporaries in the equities markets - sophisticated matching engining allowing firms to transact directly (Patterson, 2012). Instead, Enron would act as counter-party to all trades on their platform. In that sense they were a clearinghouse, but since they also considered themselves part of a trading firm, they were willing to take relatively speculative, non-standardized trades that would be difficult to offload on to other traders (McLean and Elkind, 2004).

8.5 Background on Australian Hedgers

Eastern Australia may be the single largest concentration of ENSO exposure on the planet. Given that fact, I was optimistic that Australian businesses, particularly in insurance, mining, agribusiness, and power generation, would enthusiastically support the emergence of ENSO markets.

Risk premiums on catastrophic Australian risk

What I did not appreciate before my trip to Australia was how inexpensive indemnity-based reinsurance coverage was for Australian risk. Talking to large reinsurance brokers in Sydney, I learned that indemnity coverage for most risk was written at or near actuarial fair value. Reinsurers and brokers in Bermuda and the United States were emphatic that Australian risk is under-priced and competition for that under-priced risk is fierce. One strong supporter of El Niño markets in general summed up the sentiment saying, "[g]ood luck with Australia." That news was sobering.

Australia has relatively strict prudential supervisory rules for insurers (Aon Benfield, 2009). But reinsurance prices are so low in the country that reinsurance brokers reported to me that local insurance companies routinely exceed prudential benchmarks. It will not be easy to attract Australian hedging interest to ENSO risk markets. New markets will be hard-pressed to beat the combination of low price and basis risk offered by indemnity-based (re)insurance in Australia.

With those competitive pressures in mind, I view the following as low probability firms and applications for early ENSO hedging in Australia:

- Any risk that can be packaged as business interruption or liability coverage without creating substantial moral hazard or adverse selection
- Australian insurance companies
- Utility companies and agribusinesses looking to protect assets against flood or drought

While that list is broad, it does suggest a way forward for ENSO markets. To succeed in Australia, ENSO risk markets must focus on markets that cannot or will not be covered by indemnity (re)insurance. Also, there is a niche for ENSO risk markets to service hedgers who place a premium on early payments with low legal uncertainty, a feature that indemnity payments simply cannot offer.

8.6 Hedger interviews: Australian Utility companies with a legal mandate to perform preventative maintenance

Australian reinsurance brokers offered one opportunity for covering Australian ENSO hedgers that is unlikley to be stymied by competition from under-priced reinsurance: utilities with a legal mandate for preventative maintenance of brush that tends to catch fire during El Niño.

Under drought conditions power transmission lines “arc”, igniting dry brush in the Australian outback (Hughes, 2009). In 2009, such an arc started the Black Saturday Bushfire that caused 173 deaths, destroyed over 2,030 homes, and displaced an estimated 7,562 people in Victoria[4] (Parliament of New South Wales, 2009). These fires are, however, largely preventable with careful maintenance of brush around transmission lines.

Australian courts have ruled that power transmission companies have a positive obligation to perform that maintenance and found the companies liable for property claims related to the fires. Those damages were passed to insurance companies (particularly Lloyds syndicate members) who sold liability coverage to the power transmission companies.

The reinsurance brokers I talked to in Sydney indicated that Lloyds members have concluded that there is too much moral hazard built into the liability coverage they were selling. The power transmission companies do not have the necessary incentive to perform preventative maintenance of the brush around their transmission lines. Moreover, the coverage had been so mispriced that it is unlikely that the line of business will produce a profit in the foreseeable future. Consequently, some reinsurance brokers in Australia believe that Lloyds members will not continue offering coverage for bushfires.

I believe that power transmission companies represent the best opportunity that ENSO markets have to gain a foothold in Australia:

- They clearly need and want risk coverage against the type of systemic drought in Eastern Australia caused by El Niño.
- If they can get traditional liability coverage in the future, it will be under stricter terms than in the past.
- Courts have already found these companies liable for their failure to perform preventative maintenance, so the companies should place a special premium on risk management solutions that facilitate mitigation.
- Many of those companies are parastatals with explicit mandates to use risk management tools to insulate taxpayers from the costs of their operational risks.

But, to meet the needs of those firms, ENSO coverage will have to be combined with some other parametric indexes to provide coverage for high risk conditions not related to the ENSO cycle. Specifically, the 2009 event will loom large for these hedgers and so a regional drought index will have to offer them payouts if 2009 conditions reoccurred. The climate scientists I interviewed suggested that there would be no problem constructing regional ENSO-linked indexes for hedgers. As long as the index decomposed ENSO risk, it could easily accommodate hedging on dedicated ENSO markets.

[4]Victoria is home to Australia’s second largest city Melbourne.

8.7 Hedger interviews: Peruvian banking

The Peruvian banking sector's risk was a prime focus of GlobalAgRisk's Gates Foundation sponsored work. Dr. Benjamin Collier[5] spearheaded that effort, quantifying the impacts of El Niño risk on Peruvian banks and on credit within vulnerable communities (Collier and Skees, 2012) (Collier, Katchova, and Skees, 2011). His forthcoming dissertation (Collier (2013)) provides a full treatment of the topic, so I will restrict my discussion here to briefly reviewing some of his estimates of the potential scope of the sectors' formal hedging.

Dr. Collier estimates that 8 firms (including both microcredit lenders and parastatal banks targeting larger loans) represent roughly USD 100 million in notional exposure to extreme El Niño. That estimate is based on his research of past El Niño related losses. His analysis indicates that smaller banks with lending portfolios concentrated in at-risk areas should target hedging that protects roughly 5 percent of the value of their portfolios, while larger but still geographically vulnerable institutions should target hedging of 1 percent (Collier and Skees, 2012).

The country's commercial banks are also vulnerable to El Niño shocks but their lending is better diversified. Dr. Collier estimates that their loans to highly vulnerable sectors (agribusiness, fisheries, and other financial institutions) total roughly USD 2.9 billion. So even if they formally manage a relatively small portion of that vulnerable portfolio on ENSO markets, their hedging interest alone would be of sufficient scale to justify a CAT bond issue.

8.8 Hedger interviews: Australian Hydropower

Besides power transmission firms, the second most important source of likely hedging interest are electricity producers interested in hedging reservoir levels on their hydro-power dams. Hydro-power companies manage the flood and drought risk inherent in their long term delivery contracts by actively trading electricity on spot and futures markets. They should, consequently, be excellent candidates for El Niño hedging.

I heard about two factors complicating that story when I spoke with traders in the risk management department at one large hydro-power company with assets across Eastern Australia. First, drought does not create immediate problems for hydro-power producers with large reservoirs. They face shortfalls only after successive seasons of drought. That increases the basis risk on El Niño hedging.

Second, when they do face production shortfalls, their first line of risk protection will always come from hedges on electricity markets, since they believe that those hedges have low basis risk and those markets have acceptable liquidity.

Historically, prices on electricity markets have been subject to manipulation and risen far above their long-term equilibrium in time of systematic shortfall (Cha, 2012). So, electricity hedges have a great deal of basis risk as well. But that basis risk is difficult to quantify on relatively young markets. This means that brokers may need

[5]Then with GlobalAgRisk/the University of Kentucky, now doing post-doctoral research at University of Pennsylvania's Wharton School.

to help hydro-power producers stress test their portfolios before they are willing to trade ENSO derivatives as part of their drought risk management portfolio.

8.9 Hedger interviews: Peruvian agribusiness, energy, and mining

Beyond fisheries and banking, there are large agribusiness, mining, and energy firms that face El Niño risk in Peru. I have grouped them together here because, to the extent that they would be interested in El Niño hedging, that interest would revolve around specific installations or projects. Stress tests for El Niño vulnerabilities on individual installations will not generally port simply over to other such installations. So identifying and hedging vulnerabilities in among firms in these industries will be a resource intensive process.

GlobalAgRisk has met with many such groups to discuss applications of El Niño hedging. Based on those meetings, I believe that a small subset of those groups have the sophisticated risk management, scale, and interest necessary to participate in formal hedging, given attractive pricing on their hedges. I do not believe that I can accurately estimate the aggregate size of hedging interest from these individual projects.

8.10 Hedger interviews: Australian agribusiness, mining and tourism

In addition to power transmission firms and hydro-power generators (discussed below), there are three other groups/opportunities that I could not adequately evaluate on my trip to Australia, but suspect may still be sources of early ENSO hedging. The first are Australian coal firms with assets in eastern Australia that were damaged by the 2010 and 2011 La Niña floods (Oxley, 2011). Those floods forced at least one firm, Macarthur Coal, to invoke a force majeure clause in their loan agreements (Australian Associated Press, 2011). Within the year, a larger American rival purchased the firm, despite earlier failed attempts at the same acquisition (Peabody Energy, 2011).

While traditional indemnity insurance and diversification through international mergers, I suspect that Australian mines could easily mitigate their flooding risk with strategic spending as soon as strong La Niña forecasts begin to emerge. Unfortunately, I was not able to test those suspicions on my research trip to Australia. I reached out to some of the mining groups identified by Oxley (2011) but none responded to my requests for a meeting.

Another uncertain opportunity is embedding options in loans. I met with a multinational agribusiness lender with substantial exposure in Australia. They were skeptical that their bank needed its own ENSO hedges, but they were receptive to the notion that they could implicitly bundle options with loans by offering loans with debt relief triggered by ENSO.

I discuss my experience attempting to bundle loans with insurance in Peru in greater detail in the following section on Peruvian banks. Based on that work, I believe that they are unlikely to produce much ENSO hedging in the first years of the market's existence. Many agricultural lenders in Peru had a similar reaction as the bank I spoke with in Australia. They did not want to incur any short term expense hedging their ENSO risk, but they recognized that such risks are a drag on their long-term loan performance. Consequently, they were attracted to the idea of passing those risk management costs off to borrowers. However, once the Peruvian banks saw the cost of a fully priced ENSO hedge built into a loan, they told us that their clients would be sensitive to the price difference and unwilling to sign up for risk protected loans, even with substantial education on the value of the embedded option.

The clients of large multinational agribusiness lenders are likely more familiar with formal risk management than the clients of microfinance groups in northern Peru. While that may leave them open to hearing about the value of risk protected loans, it also means that clients will have access to traditional indemnity insurance. It is not clear to me, based on my research to date, which of those countervailing factors would dominate in Australia.

Tourism risk that cannot be covered by business interruption may also provoke some hedging. Many Australian reinsurance brokers mentioned that ENSO hedging would be valuable for operations related to tourism, particularly in Northeastern Australia. Those businesses have clear ENSO risk but that risk may not translate simply into insurable interest on business interruption policies. To the extent that this is true, then some of the larger and more professionally managed tourism related businesses may provide important early support to ENSO markets. Ski resorts in the United States offer precedence for tourism related businesses adopting new weather hedges, providing important early support for new markets. My research did not reveal specific tourism-related hedging opportunities (i.e. individual businesses seeking coverage), so while I believe this is a promising avenue for hedging, reinsurance brokers and financial intermediaries with strong relationships in the industry will be critical to generating tangible hedging.

Finally, flood map coverage in Australia is poor relative to the US and much of Europe. That circumstance could provide the justification for some ENSO hedging. Given the importance of SSTs to the hydrological cycle in Australia, it is possible that insurance companies, eager to extend flood-related coverage to data-poor regions of Australia, may be willing to price their coverage as best they can, given their limited data and then imperfectly hedge their model uncertainty using ENSO derivatives. If those hedges check an insurance company's flood related exposure then they will be able to think of those early policies as loss leaders. The policies will provide them the information they need to improve their pricing over time, without the risk that they will suffer a large loss that will knock them out of the market altogether. That type of exploratory underwriting is subject to substantial moral hazard and adverse selection. Therefore, traditional reinsurance groups should be skeptical of providing coverage on pools of that risk. While that is theoretically a strong case for a derivatives or parametric reinsurance, I heard from many reinsurance brokers that such skepticism may not prevail in the current competitive environment, with reinsurance-type capital growing at an exponential rate while hedging interest for reinsurance-type risk is only growing arithmetically.

8.11 Hedger interviews: Conventional reinsurance and ILS

As I discussed in chapter 3, reinsurers and reinsurance related funds should, theoretically, be interested in selling El Niño coverage as a hedge against their own book of risk. Selling that protection would add an asset to their portfolio that is negatively correlated to their peak risk. They would effectively be paid to hedge their own books. It is rare that anyone has an opportunity to hedge their own risk directly and get paid to take that protection. (The important exception being an asset with positive return that lowers your risk through diversification. But this is distinct from an asset that has a direct, negative causal link to losses in your portfolio, an outright hedge.)

Indeed most of the ILS funds I talked to were excited to participate in an El Niño market. However, even those interested funds indicated that were unlikely to view El Niño exposure as a hedge. They saw El Niño exposure as an impressive diversifier, but not something that they could or should use explicitly for the purpose of managing hurricane exposure.

Portfolio management and basis risk

Reinsurers offered many explanations for their reluctance to hedge with ENSO markets. Some of the groups said they simply do not hedge. They said that reinsurance is a buy and hold business and that they managed risk exclusively by limiting their exposures to certain lines of business. That response was common among traditional reinsurance groups, who also indicated that they categorically did not use their balance sheets in a way that allowed for the ad hoc addition of derivative exposure, even if that exposure improved their overall risk position.

At least the first few times I heard that response, it puzzled me. Anyone in risk management should jump at the chance to get paid to hedge their own portfolios. My confusion was shared by Richard Sandor decades earlier when he first began investigating exchange-traded alternative to reinsurance:

> I had always harbored a romantic image of the group of insurance syndicates, mainly because of the 1936 movie Lloyd's of London. The movie painted the members of Lloyd's as innovative risk takers who insured the British merchant fleet during the Napoleonic wars. Lloyd's had been instrumental in helping Lord Nelson win the battle of Trafalgar. I was crestfallen and disillusioned when Bob described to me the actual lack of imagination of many of the syndicates. I found it paradoxical that those who were willing to underwrite nontraditional risks would not consider new risk management tools.

The more nuanced rejection that I heard from a few seasoned veterans in ILS/reinsurance was that risk management in their industry is focused almost exclusively on loss scenarios that threaten solvency. Basically, a reinsurer needs to worry only about making good on large claims. If years of small or moderate claims prove difficult for reinsurers, then they simply are not running their business well, and their problems are deeper than any marginal hedge could fix. To them, selling El Niño protection seemed to be just such a marginal hedge. If the premiums for hurricane risk closely matched expected losses then ENSO's marginal offset would matter a great deal to portfolio returns. But the industry insists on large markups for hurricane risk specifically to avoid having to fine tune (or over-fit) their risk estimates. (I look at a related dynamic at the end of chapter 5.)

Moreover, ENSO markets would offer hedges with a great deal of basis risk. El Niño years may, on average see, on average, 4 billion less hurricane damage in the US and Caribbean than neutral and La Niña years. But the link is probabilistic. Hurricanes have occurred in El Niño years and if, in the future, one of those storms happened to hit Miami then the hedge would be worse than worthless (i.e. leaving them to pay losses on the hurricane claims and ENSO bets that went bad).

It is possible, they said, to decompose hurricane risk, isolating some ENSO component. That decomposition may well lower expected losses. But reinsurers' lower probability loss scenarios remain unchanged or even deteriorate with ENSO hedging, since it is theoretically possible to lose money on your insurance book and on your hedge in the same season. Those scenarios will only occur with low probability. But those low probability scenarios drive capital adequacy considerations.

Uncorrelated risks and risk premiums

Not only does this basis risk problem check ENSO's value as a risk management tool, but because capital requirements for low probability events remain unchanged, it is difficult to offer clients a large discount on their coverage in recognition of ENSO's negative correlation to peak risks. The risk professionals I talked to argued that pricing for off-peak risks is driven by the the cost of reserve capital. Margins on those risks are in fact already quite low. The fact that El Niño risk is objectively better than other off-peak risks from a Markowitz portfolio prospective is immaterial.

To be sure, the connection between El Niño and hurricanes interested my interview subjects at ILS funds. But one interviewee summed up the general attitude, advocating a "soft sell." He said that industry understands that hedgers should get an attractive pricing on their El Niño hedges, but that offset may be difficult to quantify.

Dynamic risk management and live CAT trading

I also suggested to interview subjects that reinsurance related businesses could change their El Niño exposure within the predictive window, as the phenomenon looked more or less likely. Given their expertise in meteorology, this might allow them to recover some of the cost of hedges that weren't likely to be exercised. Most of the organizations I talked to, including the more traditional reinsurance groups, likened that type of strategy to *live CAT* trading, adding or subtracting storm exposure in the days and hours before a hurricane landfall.

Despite the fact that traders at those organizations personally relished any opportunity for CAT trading[6] it remains a very small part of their businesses. They

[6] They offered this opinion unprompted by me.

considered that small part speculative rather than true risk management. Moreover, they suggested a handful of organizational factors that curtailed the growth of live CAT trading:

- The capital for trading specific risks is alloted at the beginning of their budgeting cycle. That makes it difficult to change portfolios in response to emerging threats.
- The reinsurance and ILS businesses are relationship-based. One accepted way that reinsurers and ILS funds maintaining relationships with the brokers and issuers that give them access to deal flow, is to accept exposure on a deal they consider a loss-leader. That desire to maintain relationships clouds some risk management decisions. Seo (2012) laments that "...many ILS managers have become obsessed with deal access and flow. The horse-trading of good deals against marginal deals has inevitably brought about mediocre returns in the average ILS execution."
- The shareholders of reinsurance groups and ILS funds are increasingly traditional asset managers like hedge funds. Those asset managers want exposure to peak risks at high expected rates of return and believe that they can take care of their own risk management by keeping the stakes at a small percentage of their overall portfolios.

I do not accept any of those arguments as reasons why the reinsurers and ILS funds should not start selling ENSO coverage. However, these arguments are strong enough and sufficiently prevalent in the industry to undermine the pressure to sell ENSO coverage in the near term.

8.12 Speculator interviews: ILS funds

Insurance-linked security funds are eager to participate in ENSO markets. Although they would prefer that trading concentrate in CAT bonds, they expressed the will and ability to trade derivatives as well. Based on the uniformity of that reaction, I believe that ILS funds will provide all the speculative capital necessary to consummate the first round of hedging on an ENSO market.

Innovation in ILS

In a low interest rate environment, with fierce competition driving down prices for off-peak risk in particular, and a flood of new capital entering such funds, I also believe that ILS funds will speculate in ENSO markets at more aggressive prices than traditional reinsurers. Multiple top fund managers told me explicitly that this was an auspicious time to scale up El Niño/La Niña risk coverage because hedgers would receive rates that were unattainable in the market just a few years ago. One suggested that CAT bonds issued on ENSO risk would enjoy a "crushingly low price."

Regardless of its form, the first hedges placed in these markets will be loss leaders (at least in terms of opportunity cost), for the funds offering protection and the brokers arranging the deal. Both brokers and funds will naturally look to recoup some of those losses by trading on higher margin, bilaterally negotiated trades. That is one reason why they strongly prefer that ENSO markets launch as CAT bonds rather than options.

Even if bilateral negotiation does not provide brokers and funds higher margins, it does help preserve the first mover advantage that both will have for subsequent deals. Firms involved in innovative ILS trades are more likely to be contacted about similar future trades.[7] One ILS manager estimated that his fund could expect to enjoy preferential access to related deal flow for up to two years after an innovative trade. By contrast, he explained, the ability to extend that advantage is much lower if you create the infrastructure for others to do the same trade, as would be the case with exchange-traded products where all counter-parties selling protection are perceived as equals - with equal opportunity to bid on the marginal dollar of coverage extended on identical legal terms with equal counter party risk (thanks to central clearing).

ILS funds' views on ENSO options

One ILS fund manager explained that the fixed costs of trading a full options chain on ENSO would actually be higher than for individual CAT bonds. Trading a CAT bond is a one-time decision for an ILS firm. For a risk as straight-forward as ENSO, that decision would require no dedicated resources from a fund.

By contrast, if a fund decided to act as a market maker on ENSO derivatives markets, it would first need to develop a model for changing prices over time, in response to new information, just as I did in chapter 4. That will require an initial investment of expensive staff time. But the investment will not end when the model is complete.[8]

Someone will have to revisit that model every time a new trade comes in. That will require dedicated staff time, if not a full-time staff member. The cost of hiring a technically capable individual, with a background in trading, and interest in meteorology, is high.

Derivatives markets allow hedgers to enter relatively small trades. Given the opportunity, hedgers will limit themselves to especially small trades in the first days after a market opens. This means that dedicated staff will have to pay their own salary through fees stemming from a trickle of small trades until the market gains wide acceptance.

Moreover, low volumes will seed funds' suspicion that they are on the wrong side of asymmetric information. Knowing that fisheries have sophisticated proprietary anal-

[7] Seo (2012) suggests, "...the two most important qualities that attract good deal flow have been reputational value of the ILS manager, and the manager's willingness to trade counter to the market..."

[8] I believe that I've already done a great deal of the necessary work. Hence, those costs should not be prohibitive.

ysis of Pacific SSTs, funds will naturally assume that they will be at a disadvantage on a fraction of trades inside of the predictive window.

This would not be a problem if funds could operate as genuine market makers, quickly off-loading exposures to other traders. But in an illiquid market, where would-be market makers may have to inventory significant exposure as they wait for new trades, asymmetric information is a particularly serious threat.

The ILS funds I spoke to said they would only be willing to make markets within the predictive window on an exchange, if they were protected by large bid-ask spreads. That precondition might be enough to provoke a *market for lemons* problem, unraveling the whole market.

By contrast, in a bilateral market, funds would have some room for price discrimination that they could use to insulate themselves from the effects of asymmetric information - trading with groups like the fisheries only when they are extremely confident in their models.

Finally, in a related but subtly different problem, if funds were true market makers in ENSO options they would have to post bids and asks for a whole options chain (contracts with a range of triggers). This means that they would be subject not just to asymmetric information on the occurrence of large events (the primary problem in dealing with fisheries) but also to asymmetric information about every probabilistic outcome short of a catastrophic El Niño/La Niña.

By noticing pricing discrepancies between a fund's posted prices, traders could make smaller amounts of money through arbitrage. One fund manager suggested that arbitrage would "bleed to death" a single fund bold enough to act as market maker. That may be hyperbole, but it illustrates a more modest problem: that arbitrage losses could overwhelm the revenues from market making. The danger of that type of arbitrage is lower when market makers can reference an arbitrage based pricing formulas, as in equities markets. As discussed in chapter 4, no such formula is available for ENSO.

For all those reasons, if ENSO were launched on an exchange, most trades would be bilaterally negotiated *block trades*. Block trades might offer greater post-trade transparency than is currently available in ILS markets. But both trade types would offer similar pre-trade transparency (see chapter 5 for a discussion of pre and post-trade transparency,) so it is not clear that exchange-traded markets would offer clients substantially better pricing.

Transitioning ENSO from CAT bonds to exchange-traded derivatives

Those factors clearly favor ILS over options for the first iteration of ENSO markets. However, none preclude the eventual emergence of an options market. Conceivably, after an initial phase in which brokers and funds recoup the fixed costs associated with their early modeling, establish a client base, and confirm that there is in fact sufficient hedging interest to support dedicated staff, then market activity could move over to an exchange.

At that point, the primary problem in establishing liquid markets would be the incentives created by high-margin trading on ILS markets. In my interviews I heard that brokers and more traditional speculators actively opposed previous high profile attempts to move reinsurance risk to exchanges (discussed above), suggesting to hedgers that moving their business to such markets would negatively impact their working relationship going forward. One reason why some interview subjects believed that ENSO markets might succeed where those experiments failed was precisely because the entire risk market today consists only of one reinsurer selling a small policy to one client. If they launched tomorrow, there would be no entrenched interests opposing ENSO derivatives.

Exchange-traded El Niño/La Niña markets will have to pick their poison: face a collective action problem related to high start up costs now, or face a principal-agent problem in the future.

8.13 Speculator interviews: Dedicated weather trading desks

The small set of hedge funds dedicated trading weather derivatives[9] offers another promising source of interest in ENSO markets. These firms use ENSO as an input to their current trading; they are very comfortable with traded risk; and, perhaps most importantly, their trading is guided by an attitude toward risk that is diametrically opposed to that of traditional reinsurers.

I spoke at length with the head trader for one successful weather fund. He said that while it has a specific mandate to weather, the firm sees risk in generic terms. In fact, the firm traded for a substantial part of its early life without any meteorologists on staff. Then, as now, they saw their strategic advantage coming not from any particular expertise in weather but from rigorous quantitative portfolio management.

Relatively low risk-adjusted returns do not preclude their participation in any given trade. Instead, they evaluate how every trade contributes to their portfolio, presuming it offers more than a few hundred basis points ins expected value. The contrast was particularly clear in their answers to my quantitative survey. (See chapter 9.) Dedicated weather traders rarely marked any contracts as un-tradeable during the survey's calibration exercises.

Confident that they can construct profitable portfolios out of a diverse collection of risks, these funds are more concerned with the search for motivated weather hedgers. In general, they cannot find enough counter-parties to pay them to take on weather risk.

That is an important reminder for ENSO markets: even if ENSO markets are supported by aggressive speculators, eager to close bid/ask spreads, sclerotic or unbalanced hedging will stymie the development of liquidity.

All of these groups were unequivocally supportive of exchange traded El Niño/La Niña derivatives although they noted that trading volumes throughout the weather markets had fallen in recent years (confirming the story told by figures 7.10 and 7.11). OTC transactions accounted for the majority of their overall deal flow and most of their on-exchange trades were bilaterally negotiated blocks. One firm I spoke with

[9] Most of these funds are linked either to larger ILS funds or to multi-strategy hedge funds.

does not trade off-exchange and was understandably interested in seeing any ENSO risk market begin as futures and options.

As mentioned above, the large ILS funds with dedicated weather-trading groups that I interviewed indicated that they would classify ENSO risk as weather rather than catastrophe - assuming that it was traded as a derivative.

8.14 Speculator interviews: conventional reinsurance groups

El Niño coverage could act as a hedge on a traditional reinsurance portfolio. However, GlobalAgRisk's reinsurance partners priced their coverage for Peruvian banks as a speculative bet on the occurrence of El Niño, without much, if any, consideration of how the risk fit into their larger portfolios. In the first sales season, that produced a rate on line for that coverage three to four times the expected risk on the policy.[10] So, if reinsurers' first instinct is to price El Niño coverage at speculative rates, it makes sense to ask, would those same reinsurers continue to speculate on larger, more standardized ENSO markets?

The answer appears to be a qualified yes. I interviewed many conventional reinsurance groups (reinsurers as well as the host of groups that supply conventional reinsurance coverage through sidecars and collateralized reinsurance). In virtually all those interviews, managers and underwriters had similar reactions to my research agenda. They were:

- Interested in GlobalAgRisk's work;
- Encouraging of my interest in bringing ENSO markets to scale and addressing some of the issues discussed in chapter 5 (i.e. predictability, two-sided market, etc.);
- Aware of the history of exchange-traded insurance risk and pessimistic about the future prospects for the idea;
- Weary of competitive pressures in the Australian market that have driven prices to potentially unsustainably low levels;
- Open to, but not enthusiastic about, hybrid reinsurance that might contain a level of coverage with a parametric trigger for El Niño/La Niña. They suggested that reinsurers had experimented with this form of coverage, but the experiments were not successful and it is now uncommon to see such agreements. However, ENSO's opportunity for advanced payment was special in the world of insurance and clearly would be of value to clients.

Beyond those baseline reactions, traditional reinsurers' responses fell into three general categories:

[10] GlobalAgRisk helped negotiate that rate down after it became clear that the markup was a threat to sales

- “We are interested in selling El Niño/La Niña coverage, but we exclusively work with reinsurance and closely related structures.” - This response was common from the most traditional reinsurance groups including members of the Lloyds syndicate. According to underwriters and managers, the balance sheets of these groups were built to take on the liabilities of reinsurance and that was the only function they would serve for the foreseeable future. So if this coverage was not sold as reinsurance, they would not participate.

- “We are interested in selling El Niño/La Niña coverage, and we could find a way to make whatever risk coverage is available into reinsurance using transformers.” - A small subset of traditional reinsurance groups were not daunted by the unconventional nature of the El Niño/La Niña coverage I proposed. In one meeting I met with an underwriter who was especially encouraging, but skeptical of El Niño/La Niña markets. However, part-way though the meeting we were joined by the chief underwriter for the reinsurer, a three-decade veteran in reinsurance markets. After hearing my pitch for why traded markets could provide better El Niño/La Niña coverage than traditional reinsurance, the chief underwriter suggested various precedence for offering coverage that straddles insurance and reinsurance markets and even suggested that reinsurance losses in Australia would be a powerful reason why reinsurers should encourage their Australian clients toward such structures. He also said that *transformers*, groups that specialize in bringing financial agreements into and out of reinsurance markets, would be able to facilitate dual-trigger insurance policies involving coverage from capital markets (derivatives or ILS).

- “Diversification into new risks is not a core goal in our business strategy.” - After large loss events, such as Hurricanes Andrew or Katrina, new reinsurers have entered the market to take advantage of rising premium rates. Some of those groups have gradually become conventional reinsurance groups while others have continued to focus on smoothing the reinsurance capital cycle, only using their full underwriting capacity after large events. (See Froot (2001) for a detailed description of the reinsurance capital cycle.) Those groups do not actively look to balance their peak risks with new, offsetting risks. Instead, they look to compile portfolios particularly concentrated in the industry’s peak risks at temporarily high risk-adjusted returns. The few groups I talked to in this category were very interested in El Niño/La Niña, but considered the risk outside of their core strategy.

8.15 Brokerage interviews

No one set of firms working in catastrophic risk has a strong financial incentive to invest in the educational outreach needed to convince new clients of the value of hedging. Industry participants believe that there is chronic underinvestment in these activities. However, to the extent that anyone in the industry does systematically catalyze new hedging, it is brokers.[11]

Hedgers have more trust in brokers because they circulate pricing information that is especially valuable for markets with low pre- and post-trade transparency. They also value brokers because there are some economies of scale in preparing the analysis necessary to make a risk management decision. For example, an individual CAT bond sponsor may not want to license costly risk models that they may only use for a few transactions in any given year, when a broker could buy the same license to price more transactions (Schultz, 2012).

Like the funds they work with, brokers operate with a host of business models, many of which favor specific transaction types, like ILS, traditional reinsurance, retrocessional reinsurance[12], and even derivatives. I've divided my discussion of brokers into parts that reflect those business models.

Capital markets groups at large reinsurance brokerages

The capital markets groups at large reinsurance brokerages are responsible for most ILS issues. (See Evans (2012) for details on the brokers involved in a large sample of CAT bond deals.)

The most progressive capital markets groups I interviewed, described their work as shepherding catastrophe bonds from cradle-to-grave. They propose new risks and structures to hedgers. They oversee the legal and regulatory logistics of bond issues. They provide indicative pricing for bonds using risk models from RMS, AIR, and EQECAT. They work with funds to convince them to purchase their bonds. Finally, some actively trade catastrophe bonds in secondary markets. This allows them to manage risk on deals that they warehouse (hold until they can sell to a speculator), improve their understanding of available prices, and provide critical intelligence on "favorable issuance strategies. (Schultz, 2012)" Many of those brokerage groups will have employees who actively manage small ILS portfolios, just as they would at speculative ILS funds.

However, not all capital markets groups conceive of their work so broadly. A manager from one of the capital markets group said his team's function was confined to financial engineering for existing reinsurance deals, closer to the work of the *transformers* mentioned earlier. Responding to client demand, the reinsurance brokers within his parent firm propose transforming their existing deals into derivatives or securities and the capital markets group helps them to accomplish that goal. They are reticent to warehouse any risk.

Brokers in that first category were responsible for the first CAT bond issues in the mid-1990s and continue to drive innovation in ILS. I believe that their enthusiastic support is key to launching ENSO markets.

[11] Some fund managers I interviewed reported that they occasionally felt overwhelmed by brokers' proposals for new deals. They believed that most of those proposed trades were simply distractions, offering little value to their firm.

[12] Retrocessional reinsurance is reinsurance for reinsurers.

The directors of these progressive groups offered a similar reaction to exchange traded markets as the seasoned ILS fund managers mentioned above. They were skeptical of exchange-traded markets, but not antagonistic. One said that he would gladly support exchange-traded ENSO markets and indeed believed that much reinsurance risk should be traded on exchanges. However, for all the reasons discussed above, he suggested that ENSO risk markets should begin with a private CAT bond issue.

The director of one such group noted that the willingness of the ILS market to accept indemnity risk might pose a problem for ENSO markets. (See figure 7.8 for estimates of indemnity triggers' prevalence in recent CAT bond deals.) He said that investors were willing to accept indemnity risk, with its attendant moral hazard, at low mark-ups over similar parametric deals because they now accepted the risk models underlying those deals (Lane, 2013). If, as now, there is no great price difference between parametric and indemnity triggered deals, then hedgers will always prefer the low-basis risk indemnity deals. Despite that initial skepticism, he ultimately agreed that the lack of infrastructure for indemnity-based reinsurance in Peru and the value of a forecast trigger might merit a CAT bond issue covering ENSO.

Futures brokers

The opinions of one ILS broker were especially helpful in understanding the hurdles that exchange-traded ENSO derivatives will likely face. While his brokerage's primary business was retrocessional reinsurance, they were also responsible for launching the CME's hurricane markets, based on their own proprietary index.

The broker I interviewed at that firm had more direct experience relevant to ENSO futures and options than anyone else I encountered in the course of this research. Coming after almost a decade of involvement in those markets, his most important take-away lesson was powerful: start with OTC trades, then worry about moving those trades to an exchange.

In the early 2000s his brokerage designed their own parametric index for hurricanes along the eastern seaboard of the US. They took the idea to the CME, confidant that the relative cost and ease of exchange trading would lure hedgers facing this large, standardize-able risk.

Early on in the process, he noticed that most of the responsibility for generating hedging interest fell to the brokerage itself. Echoing the comments that Richard Sandor made in his book regarding the support of the CBOT for ILW markets in the early 1990s, the broker told me that I simply should not expect substantial product development support from any exchange. The marginal cost of a new contract is low for an exchange and they expect low payouts from those marginal contracts. Hence, they are reluctant to devote substantial resources to product development. This opinion was close to a consensus. In my interviews, it was echoed not just by the brokers and independent contract innovators frustrated by lackluster volumes on their pet contracts, but by current and former representatives of the exchanges themselves.

The second surprise for the hurricane contract broker was just how difficult it was to convince hedgers to open up margin accounts for trading. In his estimation, the process was neither costly nor time consuming, but it nevertheless proved too taxing for many firms new to derivatives markets. He reported that hedgers perceived the process as an upfront cost linked to a product they might never use.

Third, he was weary of other brokers incentives vis-à-vis highly transparent, exchange-traded products. Incumbents in the reinsurance industry saw hurricane derivatives as a competitor to traditional insurance and were consequently reluctant to embrace them. He suggested that some brokerages had expressed their opposition explicitly to hedgers.

Years after their launch, the CME's hurricane markets have not achieved substantial on-exchange volume. (See figure 7.13 for volumes of a similar suite of contracts launched at roughly the same time.) Interestingly, he did not consider the experiment a failure. The brokerage still uses its hurricane indexes (the rights to which they recently sold to the CME for a nominal fee) to settle many OTC contracts. He believes that if they had established that OTC volume first, the exchange-traded contracts may have enjoyed greater volumes.

Until speaking with that broker, I remained skeptical of other brokers and fund managers suggesting that ENSO markets should begin with some form of bilateral trade off an exchange. Those other individuals had at least some vested interest in keeping the risk off-exchange. However, the broker working on the CME hurricane markets clearly shared my interest in the transparency and value of exchange trading. His firm, unlike the others I spoke with, is registered with the National Futures Association (NFA) to broker deals in exchange-traded derivatives. So, he actually has a strong incentive to push volumes onto an exchange, where other brokerages, mostly lacking that designation, would not be able to broker trades. Despite that incentive, he felt strongly that ENSO's best shot at success would begin with CAT bond transactions.

Traditional reinsurance brokers

I met with traditional reinsurance brokers in Australia and Peru and found them supportive of new ENSO risk markets. In particular, the Australian brokers were optimistic about the prospects of selling to Australian hedgers, whereas fund managers and brokers in the United States and Bermuda were not. Australian reinsurance brokers brought my attention to the opportunities in the power transmission sector and feature La Niña risk prominently in their promotional literature.[13] One group in particular was eager to meet with me because they had multiple clients come to them to discuss La Niña coverage.

Those brokers clearly favor traditional reinsurance policies to cover ENSO risk but they would support CAT bonds as well. Most suggested that they were less likely to support exchange-traded derivatives except as part of a hybrid reinsurance policy.

While brokers in Australia were more optimistic about ENSO hedging than industry watchers outside the country, it is worth adding a note of caution. Some of these groups have known about GlobalAgRisk's El Niño insurance for years and have

[13]Even through La Niña is a risk they do not currently help insure.

not actively sold it to clients, despite GlobalAgRisk's pledge to support their efforts. In fact, one reinsurance broker contacted me by email to let me know that his firm already had a similar product for sale and sent me marketing materials that I had helped draft as part of my work with GlobalAgRisk. That signaled to me that there is a gap at traditional reinsurance brokers between the enthusiasm of analysts and sales teams and the institutional knowledge and support necessary to consummate reinsurance deals on an innovative risk.

8.16 Service provider interviews: Risk modelers

All of the ILS funds I spoke with mentioned the potential value of branded analytical tools that explicitly covered ENSO risk from the major catastrophe risk modeling firms (RMS, AIR, and EQECAT). Weather funds expressed a similar hope, only they focused on a different group of data and analytics firms dedicated to weather (including MDA EarthSat and Galileo).

What risk modelers do

Three firms, RMS, AIR, and EQECAT, effectively act as ratings agencies for CAT bonds and reinsurance agreements. (Note that in some cases the traditional ratings agencies also rate CAT bonds.) These large firms hire experts in natural disaster risk (geologists, meteorologists, etc.) to build stochastic simulations linking historical insurance losses to natural disasters. Although many funds perform additional analysis on new deals, the risk modelers' software provides reference pricing throughout the industry. Those models are used by brokers and firms, not just to price individual transactions, but also to model the performance of whole portfolios of risk.

It will be important to convince these firms to explicitly model the influence of the ENSO cycle on loss outcomes. My understanding is that the ENSO cycle is currently a background factor in their hurricane models. Analysts at ILS funds told me that it would be very difficult to recognize any negative correlations between El Niño and hurricanes in particular, unless that correlation were filtered through these firms' main risk models.

I spent an afternoon with analysts and managers from one of the large modeling firms. They were interested by, and optimistic about, the prospects for traded ENSO risk, although their experience with exchange-traded catastrophe products left them skeptical about ENSO futures and options.

Although they were cautious about attributing long-term changes in Pacific SSTs to climate change, the individuals I spoke to recognized the value of markets that could bridge the gap between climate and weather. They suggested that they personally wanted to see the idea succeed and were very helpful in establishing subsequent interviews.

Accuracy of risk modeling and opportunities for model arbitrage

Today's major risk modeling firms were founded in the late 1980s and early 1990s. Consequently, there remains is a great deal of uncertainty about their ability to consistently estimate catastrophic losses over a long time horizon. Nevertheless, their track record so far has been encouraging. Over the ILS market's short life, realized losses have closely matched the expected losses estimated by the large modeling firms (Lane, 2013).

But limited data is not the only reason to approach risk modeling with some skepticism. Industry watchers have noticed some opportunities to arbitrage risk models, with CAT bond issuers strategically placing their bonds using, for example, the modeling firm with the lowest estimate of expected hurricane losses Swiss Re (2012).

> On 28 Feb 2011, Risk Management Solutions (RMS) released their new US Hurricane model, causing an increase in modeled expected loss. The US Wind new issue pipeline slowed, which was a dramatic change for the market. Sponsors typically come to market at that time of year to secure protection prior to the North Atlantic hurricane season. On the release date, RMS was the modeler on 32 percent of outstanding US Wind bonds. Over USD 454 million of US Wind bonds modeled by RMS matured in 2011. Since the model change, RMS has been utilized on one natural catastrophe transaction (EQ - Worker's Comp) while AIR modeled 16 transactions and EQECAT modeled three.

That is clearly a limited sample, given the lumpiness of CAT bond issuance, but it points to one systematic weakness within the business model.

Not only could that weakness undermine the integrity or risk estimates in general, it could also have immediate consequences for ENSO risk markets. If, for example, one of the modeling firms begins offering ENSO specific analysis that encourages firms to consider managing their US wind exposure through ENSO markets, that model update may come with higher expected loss estimates for some CAT bond deals. So, hedgers looking to issue their CAT bonds using the most favorable model possible may have an incentive to systematically avoid models that encourage explicit ENSO risk management.

Funds understand the danger of model arbitrage and now routinely model their own risk using multiple firms' models. To the extent that funds continue to have a financial stake in correctly modeling outcomes (i.e. to the extent that they avoid the pass-through model common in mortgage-backed derivatives before the crash, where funds who theoretically should police model arbitrage actually encourage that arbitrage as they hold an ever smaller portion of the resulting risk), then such model averaging will check incentive problems that might undermine rational risk management, including ENSO hedging.

8.17 Service provider interviews: Climate researchers

The data that would underlie any ENSO market would come from measurement networks operated by national meteorological services (NMS). NOAA and ABM provide the most watched forecasts. I visited each and interviewed the climatologists in charge of issuing their El Niño/La Niña forecasts. Much of those discussions focused on methodology, data, and climate science. (See chapter 4 for additional methodology.) However, we also went over four key issues regarding the relationship between those NMS and any eventual risk markets using their data:

- Data release policy - the procedures NMS follow as they release data to the public;
- Transparency on data quality - full and timely disclosure of any issues that may compromise the quality of NMS data;
- Clear contingencies - alternative procedures for calculating key indexes in the event that expected data are not available or are of poor quality;
- De-politicizing forecasts - the way that markets can provide a benchmark for policy makers that frees NMS from the political pressure to alter, temper, or delay sensitive forecast warnings.

Data release policy

Currently both ABM and NOAA attempt to release monthly SST measurements on a set schedule through their websites. However, controls on data release fall well short of those for other sensitive economic data. If a reporter, for example, is particularly interested in discussing forecasts in the days leading up to that release, NMS might discuss the numbers with those reporters so that their forecasts are taken seriously and interpreted correctly as soon as they are released.

If ENSO markets allow for continuous trading based on such information, then it is imperative NMS revisit their data release protocol and put in place safe guards to ensure that all market participants have equal access to public data. The same applies to the relevant Peruvian authorities, although Peruvian data tends to focus on the Peruvian coast and would have less relevance to settlement than either NOAA or ABM. The ABM in particular was enthusiastic about standardizing data release.

Transparency on data quality

ENSO markets will settle on monthly SST averages. As straightforward as that may sound, taking an average over a whole month for a large swath of the Pacific Ocean is not simple. Take for example, satellite buoys. They may go off-line occasionally. If a malfunctioning buoy is in a closely monitored part of the Pacific, then the missing data can be safely and accurately interpolated. If, however, the malfunctioning buoy is located in a part of the Pacific with relatively low measurement density, that missing data can materially alter monthly numbers.

NOAA does a remarkable job with transparency. NOAA's National Buoy Center[14] allows the public to see recent data and even pictures from buoys throughout the TAO network that provides most ERSST SSTs. (Chapter 4 explains the difference between ERSST's in-situ measurements and the parallel satellite based dataset, OISST.) However, as ENSO markets focus the attention of new motivated parities on SST data, new transparency issues will almost certainly arise.

Clear contingencies

Data quality and quantity problems will inevitably arise in ENSO markets. In those cases, someone besides NOAA would have to take responsibility for providing settlement numbers according to a predefined contingency plan. Moreover, they would have to accept the legal liability for providing those number on-time as specified. In return for taking on this responsibility, the settlement index provider would receive a small royalty on every transaction settled based on their numbers.

Based on my discussions with multiple individuals involved in the launch of new derivatives, these royalties will be enough to pay for staff time to develop and maintain the index. However, they are unlikely to produce substantial revenues beyond that. Only a select group of highly watched financial indexes, like the Case-Shiller housing indexes and the S&P 500, provide sufficient royalty income to sustain more than the basic staff required to maintain them. I believe that the chances of an index of SSTs, which only diverges slightly from public data, generating substantial revenue are slim. The index will consist almost exclusively of NOAA measurement figures issued publicly and will only differ from those figures when there are unusual contingencies in the data.

Nevertheless, index provision will provide modest revenue to someone. My personal hope is that NOAA itself could find a means of collecting those royalties by setting up a public-private partnership. That would employ one additional climatologist specializing in analyzing the quality of NOAA's SST data and any additional revenues would go back to the NOAA offices responsible for issuing the SSTs. I talked with NOAA scientists about that possibility and they were uncertain about whether current NOAA rules allowed the agency, or an agency-endorsed public-private partnership, to accept revenues and take on liabilities.

If NOAA does not take advantage of this opportunity to collect royalties on the numbers it issues, then there are a handful of private data providers that would step in to provide the index.

De-politicizing forecasts

In Australia in particular weather forecasting is highly politicized. The climatologist I interviewed at the ABM told the story of a famous politician from an arid rural district that attempted to stop the ABM from forecasting drought. The climatologist bristled at the idea that a politician, particularly an outspoken ideologically motivated one, was interfering with a evidence-based forecasts. However, the climatologist said

[14] `http://www.ndbc.noaa.gov/`

that he had largely changed his mind after hearing the politician describing the dire consequences for individual farm households who might simply give up on their lives in the face of another year of drought.

While he sympathized with the humanitarian reasons for tempering that forecast, he was excited by the idea that a market might insulate his work forecasting El Niño/La Niña from political calculations.

The ABM has worked to switch Australia's reference point for monitoring ENSO from the SOI index to Pacific SSTs. Australians now use the SOI index as their primary indicator of ENSO related precipitation and it is so well known that the index often appears in weather forecasts alongside temperatures. However, the index is subject to volatility that is unrelated to the ENSO cycle, such as with the recent arrival of Tropical Cyclone Yazi. The ABM expert I interviewed was enthusiastic to hear that markets might be the primary reference point going forward, since that might allow him to issue forecasts without the added pressure of those forecasts being perceived as definitive by Australian politicians.

Other climate groups

Beyond NMS's data provision the climate science community will also have the chance to support ENSO markets through their research and analysis. Risk modelers hire climate scientists, but generally their work involves linking economic losses to weather, climate, and natural disaster data. That work is distinct from climate modeling and basic research on natural disasters, which still comes from academics and government scientists.[15] Industry does support that work through initiatives like the Willis Research Network and the Bermuda Institute of Ocean Sciences' Risk Prediction Initiative. Hopefully, ENSO market users can similarly support basic research into the need for and value of ENSO protection.

8.18 Service provider interviews: Exchanges

If ENSO markets launch as exchange-traded derivatives, then one of the two large US derivatives exchanges, the CME Group or the Intercontinental Exchange (ICE), will certainly be involved.

The CME Group today accounts for 80 percent of US futures trading and hosts all the standardized weather derivatives contracts in the US. That makes the exchange the most likely venue for ENSO risk. Indeed, as part of this research I spoke with a CME staff member who believes the risk fits well with their existing weather suite and hopes to leverage this research to launch ENSO contracts soon.

The ICE is a less likely destination for ENSO risk. However, ENSO's connection to energy markets, ICE's specialty, means there may be some synergies that would entice the smaller exchange into supporting ENSO markets. Trading on the ICE is dominated by energy firms. That focus has made ICE the more profitable exchange

[15] The National Center for Atmospheric Research (NCAR) is a large government supported research institution with particular relevance to ENSO.

over its short history. However, the focus has also meant that ICE has a more conservative stance on new contracts. The exchange prefers to launch products that can tap into existing liquidity, such as their recent agricultural contracts that are clones of CME futures, actually settling based on CME prices.

Marketing new contracts

Virtually all of my interview subjects with background in exchange-traded derivatives agreed on one important point: neither exchange will provide a marketing budget sufficient for ENSO to reach liquidity. Hedgers, brokers, and even exchange employees agreed that the marketing budgets for new contracts were insufficient to educate hedgers. To the extent that such markets succeed, it is because brokers and other service providers take it upon themselves to educate clients and encourage trades.

How rational is that laissez faire attitude toward new markets? Chapter 6 tells a nuanced story. On one hand, contracts that are approaching a volume of 10,000 or on a growth path to reach that threshold, are worth supporting.

On the other hand, it also shows why exchanges' current innovation strategy might be profitable. In the last decade, contracts tended not to fail outright. In fact, despite high rates of innovation, the marginal prospects of contracts remains remarkably stable. One interpretation of that result might be that exchanges like the CME and ICE should not bother to support new contracts, since the marginal prospects for contracts have been robust across time.

I do not accept that interpretation at face value, since the evidence in chapter 6 does not speak to the key counter-factual: what would have happened to contracts had they received plenty of marketing support? Especially since the work in chapter 6 presages predictive models of contract success which could target marketing investment, it would be a mistake to dismiss the hypothesis held by so many contract innovators: that their creations would have benefited from higher marketing budgets.

Exchanges and CAT bonds

If ENSO markets launch as CAT bonds, then exchanges like CME and ICE will not have much influence on their prospects. However, CAT bonds do use a different kind of exchange. The Bermuda Stock Exchange (BSX) lists almost half of the CAT bonds currently outstanding. Unlike derivatives exchanges, the BSX is not meant to be a venue for trading. Instead, the BSX enforces accounting and business conduct standards, such that listing on the exchange gives investors assurance about the integrity of the underlying issue. In that limited role, the BSX may be involved in an initial CAT bond issue.

8.19 Conclusions

I interviewed over 35 climate and finance experts on their views about key questions surrounding the launch of ENSO risk markets. Based on those interviews, there are motivated hedgers to drive early demand for formal ENSO coverage. Those early adopters include Peruvian fisheries, a few parastatal power companies in Australia, US energy firms, and international agribusiness firms, particularly those reliant on southern Brazil and Argentina.

I initially believed that ENSO products could be sold as hedges to reinsurers and ILS funds to offset hurricane losses. My interviews suggested otherwise. Those groups are unlikely to hedge in ENSO markets, thanks to entrenched business models and the basis risk inherent in hurricane hedging via ENSO.

Many hedgers' ENSO trades will offset one another. But I found that there will be plenty of speculative interest, particularly from ILS and weather funds, to correct any hedging imbalance. That finding was echoed both in my qualitative interviews and in my quantitative survey.

Despite my initial inclination toward exchange-traded derivatives, convincing me that the sturdiest foundation for successful ENSO markets will be a robust trade in bespoke hedges - either OTC derivatives or, more likely, CAT bonds. My discussion with a broker that spearheaded the CME's hurricane derivatives was particularly influential in shaping that conclusion.

While I was initially skeptical that CAT bonds could create the same social value as exchange-traded derivatives, my interviews also suggested ways to promote equitable access to CAT bond markets, boosting their positive externalities. John Seo of Fermat Capital proposed a liquidity facility that could bridge the gap between those specialized markets and social enterprises. That facility would offer small hedgers highly customizable contracts in small denominations. Those contracts would be priced using information from secondary CAT bond trading. All of the risk from the resulting portfolio of contracts would be hedged, so the facility would operate at no net cost to the host institution. This should help smooth ENSO hedgers' eventual transition to exchange-trading.

Hedgers and speculators alike need the support of analytical tools, branded by catastrophe or weather modeling firms, that link ENSO to specific business losses. Also, the national meteorological services that provide the data for contract settlement need help improving their data release procedures and converting raw data to tradeable index.

Most importantly, ENSO markets need the support of motivated brokers. The brokers willing and able to provide that support are firmly anchored in the world of reinsurance and ILS. That may be the single best reason to favor CAT bonds for ENSO risk in the short-term. Most of those brokers would be reluctant to support exchange-traded ENSO derivatives, and exchanges themselves are unlikely to make up for the loss of those brokers.

Chapter 9

Willingness-to-pay for ENSO Risk Protection

Even experts struggle to communicate their willingness-to-pay for new or unfamiliar products with many possible configurations, like an ENSO options contract. To manage that difficulty I've augmented chapter 8's qualitative analysis with an adaptive choice-based conjoint analysis - a technique used primarily in the field of marketing to infer individuals' willingness to pay for a product based on their preferences over a small set of product configurations. I obtain estimates of the willingness to pay for various ENSO contracts from a handful of the individual interview subjects. The results of that survey reinforced the message from my interviews (chapter 8): there is demand and supply that will likely cross in new ENSO markets.

To validate the qualitative results from the interview in chapter 8, this brief chapter presents:

- willingness-to-pay for various ENSO contracts from a handful of the interview subjects, estimated via adaptive choice-based conjoint analysis.

This chapter's conjoint analysis is meant to provide quantitative estimates for key parameters that are difficult to approximate through qualitative interviews, such as the elasticities of supply and demand for ENSO risk products. Importantly, respondents revealed their values for those parameters indirectly in the context of choice exercises, similar to those that financial professionals would face should such an ENSO market launch.

9.1 Adaptive choice-based conjoint

It is difficult to collect quantitative data on future purchase decisions (e.g. willingness-to-pay (sell) and demand (supply) elasticities). In hypothetical surveys respondents tell researchers that they are willing to pay more for new products than they actually are, as revealed by subsequent purchase decisions. Looking across a wide range of those studies, List and Gallet (2001) and Murphy et al. (2005), offer consensus estimates for the gap between revealed and stated willingness-to-pay ranging from 1.35 to 3 times the underlying real willingness to pay.

Given the poor results from simply asking people what they will pay for a new product or service, many economists and marketers have turned to relative preferences, estimating willingness-to-pay indirectly from the choices that people make in circumstances that are closer to how we actually shop.

Broadly, the set of survey methodologies that back-out preferences from choices is called discrete choice analysis. Discrete choice analysis covers techniques as simple as soliciting yes-or-no reactions to products at a specific price.

It also includes more sophisticated techniques like choice-based conjoint analysis, used for products with a high degree of customize-ability. At the heart of conjoint analysis, respondents are given a choice between products that are the result of random attribute sampling. For example a respondent might be asked to indicate their preference between a "red car with cruise control and a sunroof for USD 25,000" and "a black convertible without cruise control for USD 26,000."

After the respondent has answered a series of those questions, it is possible to use logit regression to back out utility measurements for each attribute. By normalizing the coefficients on each attribute (which are given in terms of utility) by the utility of the price coefficient, you can also get willingness-to-pay estimates in dollar terms. Those willingness-to-pay estimates are only valid relative to some benchmark product configuration.

Basic (i.e. *full profile*) conjoint analysis requires large sample sizes because the product configurations are generated entirely by chance. Many survey respondents have to choose among many randomized product configurations to give well-powered estimates of their utility coefficients for each attribute, even when you are estimating those coefficients for a group of people, rather than individuals. That sample size consideration presented me with two problems. First, I did not have a large sample population. There are only a handful of people with the requisite background in derivatives or insurance (preferably with expertise in weather or climate risk), willing to take my survey. Second, I had to be respectful of that population's time. Together, these limitations meant that I simply could not ask the volume of choice questions required by traditional choice-based conjoint analysis.

Instead, with the help of a donation from Sawtooth Software, I used an adaptive choice-based conjoint analysis. Adaptive choice-based conjoint analysis dynamically reconfigures each choice task based on past responses to reduce the redundancy of information revealed by each successive choice. Using those dynamic techniques, Sawtooth offers individual-level utility estimates. Those utilities can be converted into willingness-to-pay/sell estimates and those estimates can be arrayed to form supply and demand curves.

9.2 Choice-task methodology

Respondents first identified the level of each attribute that would be part of their ideal risk management tool. That provided a starting point for a multi-dimensional search problem, which the survey design algorithm uses to construct choice questions. Each questions is supposed to narrow the search space for its subsequent questions.

In the second phase of the survey, the software displays attribute combinations that respondents note are either a possibility for them to purchase (or sell, depending on whether they are hedgers or speculators) or not. The algorithm uses these questions to identify attributes that respondents consistently avoid or include in their choices. The algorithm explicitly asks if respondents consider those levels as "Unacceptable" or "Must Have" respectively.

After those first rounds, the algorithm has narrowed the acceptable search space for products of interest to the individual survey respondent. Many comparisons would

Feature	Select Feature	Cost for Feature
Underlying index	◯ NOAA NINO 3.4 ◯ NOAA NINO 3 ◯ NOAA NINO 1.2 ◯ Standard weather derivative (ex. heating/cooling degree day) ◯ Multi-peril catastrophe bond index/fund ◯ Standard energy derivative (ex. heating oil or gasoline)	0 BPS
Settlement	◯ Annual ◯ Quarterly ◯ Monthly	0 BPS
Available analysis	◯ Experts (+ 400BPS) ◯ Experts + research reports (+ 350BPS) ◯ Experts + research reports + stress testing tools (+ 300BPS) ◯ Experts + research reports + pricing formulas (+ 50BPS) ◯ Experts + research reports + stress testing tools + pricing formulas	0 BPS
Contract type	◯ Futures (payment based on index value) ◯ Options coving extreme event (payment based on index value in extreme range) ◯ Options coving events of moderate strength or worse (payment based on index value in specific range) ◯ Specialized bilateral transactions (e.g. Insurance-linked securities, swaps, etc.) (+ 100BPS)	0 BPS
Liquidity	◯ Low - ex. most single stock futures (+ 300BPS) ◯ Moderate - ex. CME housing index (+ 100BPS) ◯ Moderate plus - ex. Czech Koruna (+ 50BPS) ◯ High - ex. Platinum	0 BPS
	Total	400 BPS

Figure 9.1: Screen capture of survey - in this task respondents choose the attributes that would be part of their ideal risk management tool.

Here are a few derivatives you might like. For each one, indicate whether it is a possibility or not.

(1 of 8)

Underlying index	Standard weather derivative (ex. heating/cooling degree day)	Standard energy derivative (ex. heating oil or gasoline)	Standard weather derivative (ex. heating/cooling degree day)	NOAA NINO 3
Settlement	Quarterly	Quarterly	Monthly	Annual
Available analysis	Experts	Experts + research reports + stress testing tools + pricing formulas	Experts + research reports	Experts + research reports + stress testing tools + pricing formulas
Contract type	Futures (payment based on index value)	Options coving extreme event (payment based on index value in extreme range)	Options coving events of moderate strength or worse (payment based on index value in specific range)	Options coving events of moderate strength or worse (payment based on index value in specific range)
Liquidity	Moderate plus - ex. Czech Koruna	High - ex. Platinum	Low - ex. most single stock futures	High - ex. Platinum
Expected return in BPS above LIBOR (to the speculator)	597BPS	545BPS	1,572BPS	668BPS
	◯ A possibility ◯ Won't work for me	◯ A possibility ◯ Won't work for me	◯ A possibility ◯ Won't work for me	◯ A possibility ◯ Won't work for me

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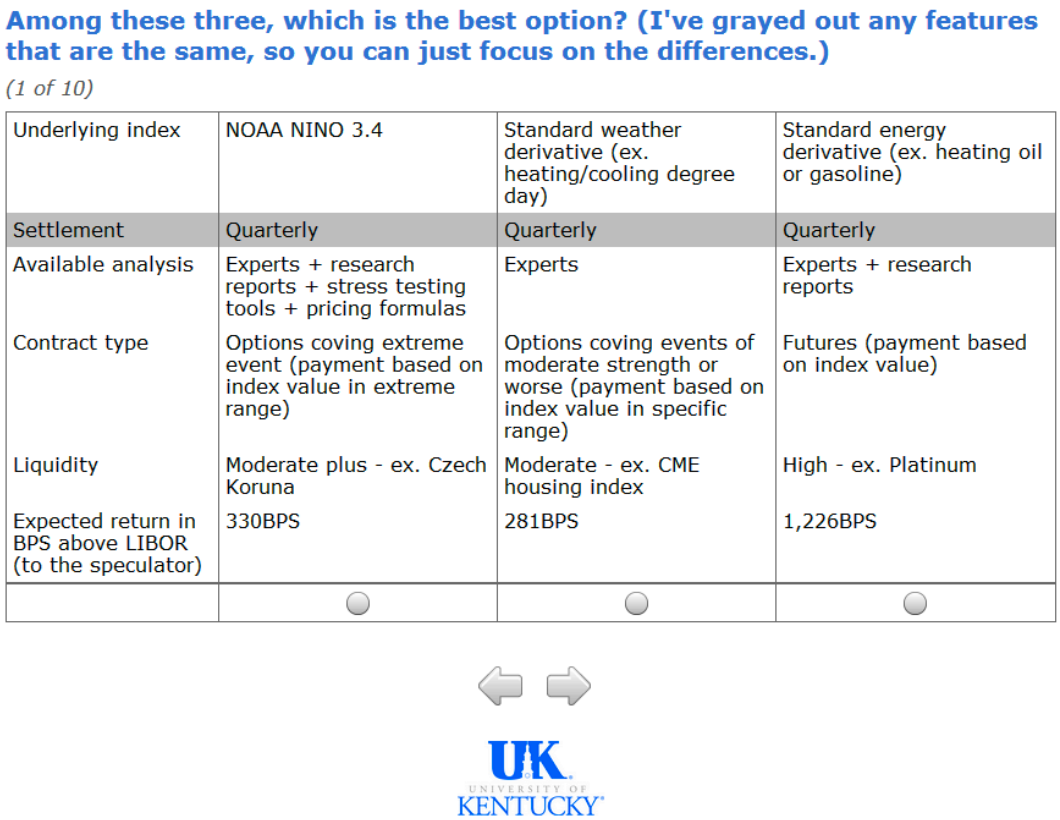
Figure 9.2: Screen capture of survey - in this task respondents indicate whether they consider algorithmically generated product configurations to be a possibility for their use.

be redundant for that respondent. For example, choosing between combinations that both contain an "Unacceptable" attribute will not provide much additional information about the relative preferences of that respondent. Attribute configurations that are still in the search space enter a Choice Tournament, where the respondent indicates their top choice among successive displays of three full product configurations. The winning concept from each set of three advances to the next choice set, while its new competitors are assembled from within the remaining search space. The Choice Tournament continues until a winner is determined (a combination that apparently cannot be beat) or a maximum number of questions have elapsed. To the extent that Sawtooth explains its search algorithm, it is available in Johnson and Orme (2007) and Orme (2009b). Similar algorithms for adaptive conjoint analysis are discussed in greater detail in Toubia et al. (2003) and Toubia, Hauser, and Simester (2004).


Among these three, which is the best option? (I've grayed out any features that are the same, so you can just focus on the differences.)

(1 of 10)

Underlying index	NOAA NINO 3.4	Standard weather derivative (ex. heating/cooling degree day)	Standard energy derivative (ex. heating oil or gasoline)
Settlement	Quarterly	Quarterly	Quarterly
Available analysis	Experts + research reports + stress testing tools + pricing formulas	Experts	Experts + research reports
Contract type	Options coving extreme event (payment based on index value in extreme range)	Options coving events of moderate strength or worse (payment based on index value in specific range)	Futures (payment based on index value)
Liquidity	Moderate plus - ex. Czech Koruna	Moderate - ex. CME housing index	High - ex. Platinum
Expected return in BPS above LIBOR (to the speculator)	330BPS	281BPS	1,226BPS

Figure 9.3: Screen capture of survey - in this choice tournament question respondents identify their preferred risk management tool from among algorithmically generated options.

9.3 Estimating utilities through hierarchical Bayesian analysis

Responses to choice tasks are converted into utility scores through a multi-level Bayesian model. Individual utility scores for specific attributes (*parts-worth*) are modeled using a multivariate normal distribution:

$$\beta_{\text{respondent,attribute}} \sim \mathcal{N}(\mu_{\text{attribute}}, \sigma_{\text{attribute}}) \tag{9.1}$$

Where:

- $\beta_{\text{respondent,attribute}}$ is the utility score that a respondent assigns to an attribute;
- $\mu_{\text{attribute}}$ is the average utility score of all respondents for an attribute, and;
- $\sigma^2_{\text{attribute}}$ is the variance of that utility score (which is part of a matrix, D, of variances and covariances of the distribution of parts-worth across individuals).

Those utility scores are linked to respondents' actual choices through a multinomial logit model. The probability that an individual chooses a certain product given the options in a choice task is denoted $\Pr_{\text{respondent}}(\text{product}_{\text{choice task}})$ and defined as:

$$\Pr_{\text{respondent}}(\text{product}_{\text{choice task}}) = \frac{\exp\left(\sum_{\text{attribute of product}=1}^{\text{max attributes in product}} \beta_{\text{respondent,attribute}}\right)}{\exp\left(\sum_{\text{product in choice task}=1}^{\text{max products in choice task}} \sum_{\text{attribute of product}=1}^{\text{max attributes in product}} \beta_{\text{respondent,attribute}}\right)} \quad (9.2)$$

Parameters β, μ, D are estimated via Gibbs sampling (Orme, 2009a).

$\beta_{\text{respondent,attribute}}$ are denominate in utils. However, the choice tasks include price as one variable attribute. So we also get a parameter estimate for $\beta_{\text{respondent,unit price}}$ that gives us a ratio of utiles to price units for a given respondent. In this case, the price units are basis points above LIBOR in expected return.

Normalizing the other parts-worth parameters by that utility of price, gives us a willingness-to-pay/sell denominated in basis points. Note that those willingness-to-pay/sell estimates are only valid relative to some baseline. In this case, I choose a standard multi-peril CAT bond for my baseline. A standard multi-peril CAT bond is indicated in the survey as a "bilaterally negotiated contract, traded at low volume, settling annually on a multi-peril CAT bond index/fund, supported by experts, research reports, and stress testing tools."

9.4 Results

Tables 9.1 and 9.2 provide utility scores[1] for hedgers and related service providers ($n = 8$) and speculators ($n = 7$) respectively.

Clearly, this is a small sample. The standard deviations on the utility scores in tables 9.1 and 9.2 reflect that. Very few of the mean estimates are more than two standard deviations away from zero.

Bayesian analysis generally does not use simple thresholds for statistical significance. Instead, parameters with wider posterior distributions are interpreted as subject to greater uncertainty than those with tighter distributions. So, these estimates should not be disregarded, especially given the fact that the sample driving that uncertainty is representative of the small community of people who might be in a position to buy, sell, or advise on ENSO derivatives. However, the evident uncertainty in the estimates does suggest that beliefs formed from these results should be held loosely.

[1] Note that the utility scores are zero-centered across each attribute category.

Table 9.1: Average utilities (zero-centered differences) of product characteristics for hedgers and service providers

Characteristics	Average Utilities	StDev
NOAA NINO 3.4	39.70	18.67
NOAA NINO 3	-8.64	51.30
NOAA NINO 1.2	-13.29	52.48
Standard weather derivative (ex. heating/cooling degree day)	8.40	25.09
Multi-peril catastrophe bond index/fund	-11.75	91.00
Standard energy derivative (ex. heating oil or gasoline)	-14.42	29.69
Annual	-22.63	53.66
Quarterly	5.89	18.53
Monthly	16.75	44.30
Experts	-21.70	22.92
Experts + research reports	7.96	23.18
Experts + reports + stress testing tools	3.22	26.78
Experts + reports + pricing formulas	-2.42	17.24
Experts + reports + stress testing + pricing	12.94	29.64
Futures (payment based on index value)	5.45	29.29
Options covering extreme event	26.83	16.41
Options covering events of moderate strength	14.03	33.46
Specialized bilateral transactions	-46.30	62.47
Low - ex. most single stock futures	-29.90	25.68
Moderate - ex. CME housing index	11.41	39.81
Moderate plus - ex. Czech Koruna	-3.04	26.59
High - ex. Platinum	21.54	39.54
E[annual return above LIBOR] = 40 BPS (to the speculator)	51.72	64.93
E[annual return above LIBOR] = 2280 BPS (to the speculator)	-51.72	64.93
None	48.67	27.07

Table 9.1 suggests that hedgers prefer:

- Niño 3.4 to Niño 1.2 or Niño 3;
- monthly contract settlement to annual or quarterly;
- more available analysis for their trades, and are particularly weary of products in which hedging decisions are only supported by expert opinion;
- options on extreme events (they are disinclined toward bilateral transactions);
- more liquid contracts;
- paying less for hedges (i.e. they show higher utility for paying 40 basis points above LIBOR than for paying 2280.)

Table 9.2: Average utilities (zero-centered differences) of product characteristics for speculators

Characteristics	Average Utilities	StDev
NOAA NINO 3.4	23.52	18.41
NOAA NINO 3	-21.40	18.16
NOAA NINO 1.2	-13.59	15.09
Standard weather derivative (ex. heating/cooling degree day)	23.73	22.99
Multi-peril catastrophe bond index/fund	-1.67	53.16
Standard energy derivative (ex. heating oil or gasoline)	-10.58	14.73
Annual	9.63	25.42
Quarterly	2.69	17.43
Monthly	-12.33	25.30
Experts	-33.61	37.08
Experts + research reports	-9.64	25.19
Experts + reports + stress testing tools	5.29	16.06
Experts + reports + pricing formulas	13.63	30.68
Experts + reports + stress testing + pricing	24.33	40.81
Futures	-13.00	34.59
Options covering extreme event	5.15	11.58
Options covering events of moderate strength	2.65	23.60
Specialized bilateral transactions	5.20	26.45
Low - ex. most single stock futures	-12.24	18.60
Moderate - ex. CME housing index	19.38	20.02
Moderate plus - ex. Czech Koruna	-9.32	12.72
High - ex. Platinum	2.18	21.36
E[annual return above LIBOR] = 40 BPS (to the speculator)	-141.69	52.54
E[annual return above LIBOR] = 2280 BPS (to the speculator)	141.69	52.54
None	-63.53	77.47

Table 9.3: Average importance of product characteristics for hedgers and service providers

Characteristics	Percent	StDev
Underlying index	21.39	12.91
Settlement	12.02	12.40
Available analysis	11.52	5.14
Contract type	17.04	10.98
Liquidity	15.37	3.99
Expected return in BPS above LIBOR (to the speculator)	22.65	14.89

Table 9.4: Average importance of product characteristics for speculators

Characteristics	Percent	StDev
Underlying index	14.85	6.35
Settlement	7.77	4.17
Available analysis	12.33	9.98
Contract type	9.53	4.89
Liquidity	8.29	3.83
Expected return in BPS above LIBOR (to the speculator)	47.23	17.51

By contrast, table 9.2 suggests that speculators prefer:

- contracts settling based on standard weather indexes or Niño 3.4 (between which they are largely indifferent) to all other indexes;
- annual to quarterly or monthly settlement, but not by a large margin;
- also to trade with more available analysis;
- options on extreme events and bilateral transactions (between which they are indifferent) to other contract forms;
- moderately liquid contracts;
- to be paid more for hedges.

Most of these inferences are obvious or reinforce what I found qualitatively in my interviews.

In tables 9.3 and 9.4 the variance within utility scores for a given attribute category is compared to the variance across attribute categories to provide a measure of the importance of each product category to hedgers' and speculators' choices (Orme, 2009b). They show that speculators' decisions are driven by price. Hedgers also look first to price, but it is not their only concern. Price is roughly as important to hedgers as other product attributes. Inference about hedgers' price concerns are subject to greater uncertainty than for speculators.

I converted the raw utility score estimates of individual respondents (not zero-centered as in tables 9.1 and 9.2) into willingness to pay/sell relative to a standard

CAT bond. By taking the empirical cumulative distribution function of those individual estimates of any given product configuration (and taking the inverse of that function for hedgers), I put together supply and demand curves for various product designs. The supply curve, for example, shows what percentage of the surveyed speculators would be willing to sell at an expected return denominated in basis points over LIBOR, relative to a standard multi-peril CAT bond.

Figure 9.4 displays those curves for monthly settled Niño 3.4 contracts. Each column of graphs shows the curves for a different contract type. Each row corresponds to a different level of supporting analysis available to hedgers and speculators. Within each graph, colors distinguish supply and demand curves for hedgers and speculators operating under different liquidity levels. For example, the green line in each graph shows a demand curve for monthly settled Niño 3.4 protection with high liquidity.

One clear lesson from figure 9.4 is that speculators have remarkably uniform willingness-to-sell. Almost regardless of the underlying product configuration, they will sell Niño 3.4 protection at rates ranging from a bit above a standard CAT bond to a bit below. As we saw in table 9.4 the elasticity of supply is high, with risk managers responding to expected returns above all else.

Froot (1999) discusses monopoly pricing power in catastrophic risk markets. Given that possibility, figure 9.4 provides some cause for concern. The most motivated hedgers in the survey appear price insensitive. This suggests that if one or two risk sellers were able to isolate the most motivated hedgers, and avoid creating a competitive market for ENSO protection, they may enjoy some pricing power.

Fortunately, figure 9.4 also shows that most hedgers are sensitive to price and that the market will clear in that elastic region of the demand curve. At the clearing price (just above the CAT bond average), most of the hedgers in the sample would have coverage.

That accords roughly with my interviews, which suggest that prices in the ENSO market will be linked to those in the CAT bond market. Unlike the survey, however, my interviews suggested that ENSO will be on the low end of the CAT bond pricing spectrum. The survey also indicates that there will be risk taking capacity to meet virtually all demand for ENSO coverage. It is encouraging to see that respondents' opinions do not change fundamentally after being filtered through a sophisticated preference elicitation routine.

9.5 Conclusions

This final chapter supports the qualitative findings in chapter 8. It presents the results from an adaptive choice-based conjoint analysis, arranged to form indicative supply and demand curves for a host of ENSO risk management products. Those supply and demand curves suggest that there is latent demand and supply that will cross. The market will clear at prices that offer speculators expected returns similar to those from multi-peril CAT bonds. That is above the markups indicated by speculators in the interviews profiled in chapter 8. Additionally, the curves suggest that there will be elastic demand at the market clearing price. That means that speculators will have limited opportunity to exercise pricing power.

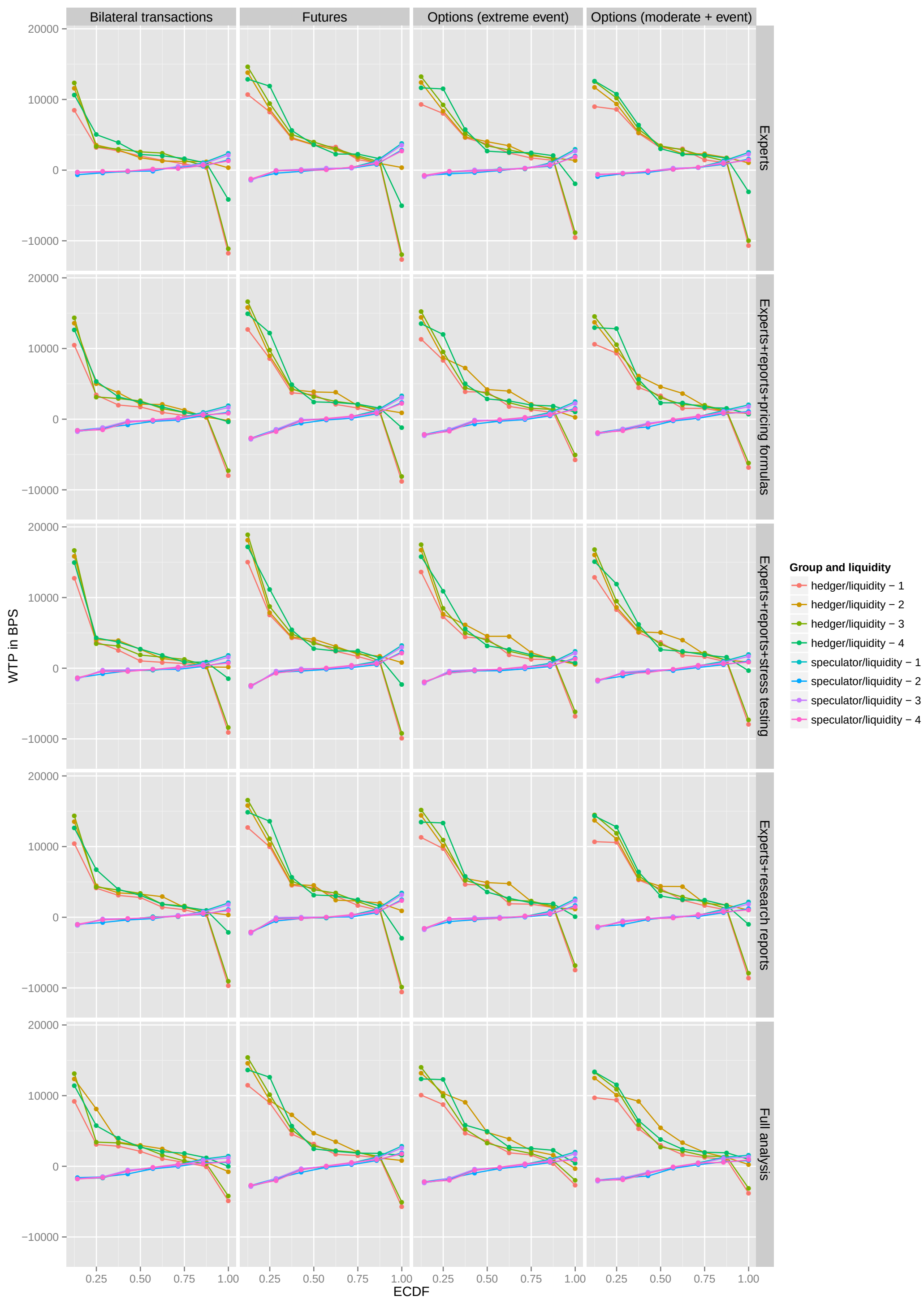


Figure 9.4: Relative supply and demand curves for monthly settled Niño 3.4 contracts. Willingness-to-pay/sell is in basis point relative to a standard multi-peril catastrophe bond. See figure 7.7 for recent benchmark prices for catastrophe bond risk. Estimates are based on the raw utility scores of individuals in an adaptive choice-based conjoint survey. The survey includes seven speculators and eight hedgers and related service providers. Estimation was completed with Sawtooth Software.

In general, speculators were willing to offer any risk management contract, given a high expected return on the underlying risk. By contrast, hedgers' purchase decisions will take into account a wider array of considerations, including the contract type (ILS, futures, options, etc.). As expected, hedgers have stronger preferences for specific underlying indexes than speculators.

These findings are subject to substantial uncertainty, given the size of the underlying sample. However, they provide important validation of the interviews in chapter 8. Past studies suggest that qualitative interviews have been unreliable in revealing willingness-to-pay for unfamiliar products types. Researchers have documented better predictive insight from the type of choice-based survey used in this chapter.

Together, the chapters suggest that ENSO markets will be supported by latent demand and supply sufficient for formal risk management trades in the near-term.

Chapter 10

Conclusions

Climate risk is a growing concern for hedgers across the globe. Yet, those hedgers have never had the opportunity to manage that risk on traded markets. There are markets that cover the *policy responses to climate risk* through, for example, emissions permits. But those markets are only tied indirectly to climate - their prices fluctuate with changes in regulation. Exchange-traded weather indexes allow firms and institutions to manage risks like high summer temperatures in a given city. But it is difficult to see global scale climate change just by looking at the individual cities and regions those markets cover. Indeed, because those markets are so localized they miss the chance to attract liquidity from the diverse groups of hedgers that face dire consequences from changing weather patterns across the planet. That limited scale may explain some of their struggle to establish liquidity.

In this dissertation, I looked at the prospects for markets covering phenomena that sit between those poles of weather and climate. In particular, I focus on El Niño-Southern Oscillation, the climate system whose extreme behavior (El Niño/La Niña) causes catastrophic weather across the globe.

I've researched the potential size of ENSO markets (chapter 2), those markets' chances for growth on an exchange (chapter 6), and the preferences of its likely early adopters (chapter 8). Along the way I also put together tools to support ENSO markets (chapter 4 and appendixes Appendix O: December Pricing through Appendix D: January Pricing) and offered suggestions about how they could best serve the public interest (chapter 5).

10.1 Final judgment

Over the last years, whenever I've discussed this research, I've invariably been asked: So what do you think? Are there going to be ENSO markets? Do these things really have a shot?

After all this research, I do believe that ENSO markets will begin in the next few years. More importantly, I see a strong chance that those new markets will tap into large and balanced hedging interest.

While this work reinforced my intuition about the emergence of ENSO markets, it shifted my opinions about the forms that ENSO markets should take. My early research led me to believe that ENSO trading could be channeled into standard exchange-traded derivatives. I thought that those markets offered a combination of competition, transparency, and dynamism unavailable from reinsurance, CAT bonds, or other specialized derivatives. I was skeptical of arguments against futures and options, because I believed that they were born out of the self-interest of firms that benefited from opaque markets.

I still believe that the natural home for ENSO risk is on futures and options exchanges. However, risk professionals, some of whom have experience pushing natural catastrophe risk on to exchanges, convinced me that the shortest path to liquid futures and options is not the most direct. In the near term, CAT bonds can offer well-priced protection to hedgers but simultaneously attract the investment from brokers and other service providers. That investment is necessary for future growth. Without it, I believe that ENSO markets will be stunted.

During that start-up phase, there will be opportunities to support the socially beneficial hedging that might otherwise be a casualty of launching in a form (CAT bonds) accessible only to institutional investors. John Seo of Fermat Capital proposed a liquidity fund that will help smaller investors access customized coverage linked to, but not directly from, CAT bond markets. That fund would offer socially important institutions and firms access to the same customized, small transactions that are usually only available on options markets. The prices of those transactions will come from secondary CAT bond trading and all of the risk of the resulting portfolio of ENSO hedges will be sold on to financial firms. That means that the liquidity facility could offer small hedgers valuable coverage at no net cost to its host institution. Eventually the hedging activity from both the CAT bonds and the liquidity facility, could be ported over to futures and options markets.

10.2 Hedging and poor communities

In the introduction to this dissertation (Introduction: Direct Climate Markets), I discussed how hedges, specifically the types of climate hedges that I proposed in this dissertation, are economically efficient and raise the value of the firms that use them.

But the fact is that no one at GlobalAgRisk became interested in El Niño risk because it would boost the value of large fishing and mining companies in Peru. GlobalAgRisk and its funders' interest was in improving the resilience of poor communities to natural disasters. So how does this dissertation relate to poverty? Does hedging create value for poor communities?

Some economists argue that, just like firms, the poor do not need formal risk management. Households are already very sophisticated risk managers. Most are plugged into informal networks that constantly circulate income through money lending, remittances, and economic contracts incorporating elements of barter (such as sharecropping). Surveying rural Nigerians, Udry (1994) showed just how sophisticated these networks can be (Banerjee and Duflo, 2011):

> ... at any point in time, the average family owed or was owed money by 2.5 other families. Furthermore, the terms of the loans were adjusted to reflect the situations of both the lender and the borrower. When the borrower suffered a shock, he would reimburse less (often less than the original loan amount), but when it was the lender who had hit a rough patch, the borrower would actually repay more than he owed. The dense network of mutual borrowing and lending did a lot to reduce the risk that any individual was facing.

Robert Townsend of MIT describes this type of informal risk sharing as an "implicit mutual fund" in which the community "[eats] the dividends" (Roberts, 2011).

In snapshot surveys, these schemes provide solid protection against household loss. They minimize the variance of consumption as well as formal insurance, but without many of the costs associated with that insurance. Townsend (1994) estimates that the mutual fund is so effective, that a dollar increase or decrease in income only translates to a change of roughly 20 cents in consumption.

But, just as with hedging on the firm level, there is substantial academic research detailing drawbacks to informal risk management. Informal risk management networks break down, particularly in the face of correlated risks like natural disasters. When they do, families suffer (Gertler and Gruber, 2002) (Fafchamps and Lund, 2003). Not only are informal risk management networks subject to periodic lapses, but within those networks, households change their investment and production decisions, mirroring the largest firms on the planet. They favor low-risk, low-return economic strategies at high cost to their future wealth (Zimmerman and Carter, 2003) (Morduch, 1994). Looking specifically at climate, Rosenzweig and Binswanger (1993) finds that poor farmers paid an implicit penalty of 35 percent of their potential annual profits to manage their rainfall risk through low-risk, low-return cropping strategies.

When risk changes the investment decisions of firms, markets miss opportunities to complement informal risk networks through services like lending. Collier, Katchova, and Skees (2011) shows how microcredit borrowers in Peru implicitly pay higher rates because their banks do not formally manage El Niño risk. That investment problem extends all the way down the economic value chains linking rural communities to the global economy. Agricultural input suppliers, commodity processors, logistics firms, and many other important firms hold back from investing in at-risk regions because those firms themselves do not manage natural disaster directly.

Rural communities could avoid these traps through microinsurance schemes. The first randomized controlled trial offering subsidized microinsurance against weather to farmers in Ghana showed that the insurance was effective at mitigating household consumption shocks (Karlan et al., 2011). A more recent trial, profiled in Cole, Giné, and Vickery (2011), showed that weather insurance schemes cause farmers to shift production towards the higher-return, higher-risk cash crops that they avoided in the informal risk networks documented in Rosenzweig and Binswanger (1993).

Perhaps the simplest policy response to that research would extend subsidized crop insurance to rural communities in the developing world. Unfortunately, that basic idea is decades old and has proven disappointing. Projects have repeatedly bumped into the same roadblocks of basis risk, moral hazard, adverse selection, tepid take-up, and fiscal instability. (Skees, Varangis, and Siegel (2002) and Mahul and Stutley (2010) provide excellent overviews of these historical difficulties.)

So, microinsurance is caught in a difficult position. On one hand subsidy schemes have consistently disappointed development economists. On the other hand, unsubsidized microinsurance comes to rural households at a steep opportunity cost. The marginal return to investment in rural households is actually very high, measured both directly, as in Duflo, Kremer, and Robinson (2008), and indirectly, though the very high rates they pay on microcredit loans highlighted in figure 22. That productivity means that a dollar spent on formal risk management involves a great deal of foregone growth, growth that could provide households with a greater asset base when they do eventually face a shock. Having a larger asset base is, in some sense, a type of insurance itself because in the wake of a disaster, it is generally the poorest households that have to make the compromises (selling assets, eating less, etc.) with the most serious consequences for long-term growth. To the extent that not insuring can facilitate households' short-term growth, then those households will have to make fewer of those tragic compromises and that should be taken into consideration as we assess the value of this insurance for households (Cavanaugh, Collier, and Skees, 2010). Cavanaugh (2011), simulates a poor rural household facing El Niño risk. When the opportunity cost of that insurance is high, as is the case for an El Niño insurance with a sales closing well in advance of the period of coverage, that study indicates that pushing households toward expensive insurance does endanger their long-term economic prospects.

Formal risk management is important for poor communities, but the schemes to bring that risk management down to the household level are unsatisfactory. So, how can hedging support poor communities?

GlobalAgRisk has worked to improve the resilience of poor communities by making sure that firms and institutions that could complement existing risk management schemes have access to flexible, fairly priced risk coverage (Murphy et al., 2011). Poor households should know, for example, that if they pay back their loans today, they will have access to more credit when they need it most, after a disaster. Agricultural input providers should expand their operations in regions subject to manageable risk, improving the price and availability of vital economic inputs. Whole industries already invested in poor regions should not face bankruptcy because they cannot access formal risk management tools.

I believe that traded markets in ENSO and other teleconnection risks are exactly the type of financial tools that would support resilience in poor communities. Moreover, they are scalable - working equally for the teleconnection risks faced by a poor household as for a large firm.

To be sure, I do not hope that these tools help turn small farmers into bond traders. To paraphrase Banerjee and Duflo (2011), "the poor [should] not need to be the hedge-fund managers of their own lives." Instead, my preference is that they become part of a larger system of stable, well-priced, and forward-looking risk management.

10.3 Finance is a means, not an end

As ENSO and related markets develop, I hope that we remember that finance is and always will be a tool rather than an end in and of itself. Despite this dissertation's focus on liquidity, these markets will never be important *because* people use them. They will be important contingent on *how* people use them.

Robert Shiller, a Yale economist who has devoted much of his career to developing new risk management tools for middle-class Americans, states that beautifully in his philosophical response to the most recent global financial collapse, *Finance and the Good Society* (Shiller, 2012):

. . . At its broadest level, finance is the science of goal architecture - of the structuring of the economic arrangements necessary to achieve a set of goals and of the stewardship of the assets needed for that achievement. The goals may be those of households, small businesses, corporations, civic institutions, governments, and of society itself. Once an objective has been specified - such as payment for a college education, a couple's comfortable retirement, the opening of a restaurant, the addition of a new wing on a hospital, the creation of a social security system, or a trip to the moon-the parties involved need the right financial tools, and often expert guidance, to help achieve the goal. In this sense, finance is analogous to engineering.

It is a curious and generally overlooked fact that the very word finance actually derives from a classical Latin term for "goal." The dictionary tells us that the word derives from the classical Latin word finis, which is usually translated as end or completion. One dictionary notes that finis developed into the word finance since one aspect of finance is the completion, or repayment, of debts. But it is convenient for our purposes to recall that finis, even in ancient times, was also used to mean "goal," as with the modern English word end.

Most people define finance more narrowly. Yet financing an activity really is creating the architecture for reaching a goal-and providing stewardship to protect and preserve the assets needed for the achievement and maintenance of that goal.

The goals served by finance originate within us. They reflect our interests in careers, hopes for our families, ambitions for our businesses, aspirations for our culture, and ideals for our society; finance in and of itself does not tell us what the goals should be. Finance does not embody a goal. Finance is not about "making money" per se. It is a "functional" science in that it exists to support other goals - those of the society. The better aligned a society's financial institutions are with its goals and ideals, the stronger and more successful the society will be. If its mechanisms fail, finance has the power to subvert such goals, as it did in the sub prime mortgage market of the past decade. But if it is functioning properly it has a unique potential to promote great levels of prosperity.

Chapter 11

Arctic Oscillation (AO)

If ENSO markets reach sustainable liquidity, then there is a host of similar climate anomalies that could follow it onto traded markets. The climate professional I interviewed, believe that the Arctic Oscillation (AO) will lead that second wave of teleconnections markets. Like ENSO, AO is closely watched by energy firms today.

This epilogue introduces AO and its promise as a traded index, including:

- a description of the AO as a climate phenomenon;
- a review of what current climate science tells us about its impacts;
- a discussion about how the underlying index is calculated; and,
- statistical analysis of the correspondence between the ENSO index and disaster impacts around the world.

11.1 Introduction to the Arctic Oscillation (AO)

The Arctic Oscillation (AO) (often called the Northern Annular Mode (NAM)) refers to changes in a wall of atmospheric pressure and wind that normally holds cold Arctic air in the polar region. During the northern hemisphere winters, when the index measuring AO is positive, the wall is particularly strong - a ring of air currents, blowing west to east (also called the Westerlies) keeps cold Arctic air trapped in the low pressure zone of the Arctic. This results in relatively warm wet winters in much of the United States east of the Rockies and Northern Eurasia, with an increase in European wind storms (Hurrell et al., 2003). Positive anomalies are also associated with lower than average precipitation in the American west and Spain (McAfee and Russell, 2008) (Raible, Luksch, and Fraedrich, 2004).

In contrast, when the index is negative, the barrier holding cold air in the Arctic is weak and the atmospheric pressure at the North Pole is high. During negative AO anomalies, cold Arctic air penetrates into the *middle latitudes* - the region around 45 degrees North, which runs roughly through Montreal Canada, Bordeaux, France, the Northern tip of Sapporo Island, Japan and Portland, Oregon.

Negative anomalies in the AO are associated with winter storms. In February 2010 NOAA registered the largest negative anomaly in the Arctic Oscillation (a value of 4.266) in the agency's basic times series (beginning in 1950). That month there were three historic winter storms in the mid-Atlantic United States. The first two storms, arriving within days of one another, shut down Washington, DC and produced monthly snowfall records roughly 25 percent above previous historic highs for Baltimore and Washington DC. Klein, Lasorsa, and Cohen (2011) Oceanic and Administration (2010) and Seager et al. (2010) suggest that these extreme snowfalls, as well as higher than normal snowfall in northwestern Europe during 2009-2010, were indeed driven by the negative phase of the AO. Cohen et al. (2010) comes to similar conclusions. This coupling of extreme index values and high profile natural catastrophes with large economic impacts may be important for attracting hedgers to an AO market. Vivid examples of a hazard appear critical to prospective hedgers' perceptions of risk, especially in the context of extreme weather, where individuals may have difficulty estimating expected losses (Browne and Hoyt, 2000) (Johnson and Tversky, 1983) (Kunreuther et al., 1978) (Kunreuther and Slovic, 1978) (Denes-Raj and Epstein, 1994) (Denes-Raj and Epstein, 1994).

Viewed in isolation, the index appears to be a random walk, flipping signs every few weeks. (Given this random-walk behavior, the AO is not a true oscillation, which explains why many scientists have switched from the more popular name, the Arctic Oscillation.) However, recent work including Baldwin et al. (2003), climate scientists have shown some mid-range predictive skill for the AO index, hints that the anomaly may show longer-term trends. This could be important for attracting speculators to an AO market, as it offers the possibility of profitably trading on private forecasts.

Over the past few decades the AO has tended towards higher index values. This tendency remains subtle. Winter index values reject non-stationarity with 95 percent confidence when subjected to the Augmented Dickey-Fuller test for the presence of a unit root. Nevertheless, climate experts have found this upward bias in repeated studies and believe that it likely reflects climate change associated with greenhouse gas emissions or changes in ozone layer (Gillett et al., 2002; Shindell et al., 1999). This connection to global climate change means that a derivatives markets based on AO will provide an important leading indicator for global climate change, perhaps even better than ENSO, which has shown a similar upward bias. Whereas prices on existing climate markets (such as those for carbon dioxide emissions) are contingent on government regulation in response to climate change, prices on an AO market will respond to global climate change itself, insofar as it impacts the index.

AO is often associated to two other important climate indexes. First the Antarctic Oscillation (AAO) (or Southern Annular Mode (SAM)) is a similar anomaly affecting the Southern Hemisphere. Only a handful of the world's southernmost countries peak into the zone impacted by AAO, so it has understandably received less research attention than its northern twin (Bridgman and Oliver, 2006). Second, some climate scientists consider the AO the parent of the North Atlantic Oscillation (NAO) (Wallace, 2000). I discuss neither the AAO nor the NAO in depth here.

11.2 Index construction

NOAA's index tracking the AO is derived from atmospheric pressure patterns in the northern hemisphere measured between 20 degrees latitude (landmark cities roughly at this latitude include Mumbai, India and Mexico City, Mexico) and 90 degrees latitude (the North Pole). NOAA uses satellites to measure the height above the sea surface level (adjusted for the differing effects of gravity at difference places on earth) that gives an atmospheric pressure of 1000 hectopascals (hPa). The actual index is a statistical abstraction (the leading Empirical Orthogonal Function (EOF)) of the daily and monthly mean anomalies of those pressure measurements.

Empirical Orthogonal Function (EOF): reducing the multi-dimensional data into one number

It is difficult to synthesize a matrix of values taken at different times across many locations, even when the resulting matrix is projected onto a series of maps. Imagine looking at a matrix of daily temperatures for major cities across the globe. How can you say from that matrix that the earth, as a whole, is cold or hot? Even if know something about the spatial array of those cities, you can assign virtually any weight each city's contribution to the global temperature.

Climate scientists routinely face that problem. In the case of AO, they distill a single tractable index covering the atmospheric pressure across the AO zone using a statistical transformation called an Empirical Orthogonal Function (EOF). That transformation involves (Bjornsson and Venegas, 1997):

1. Constructing a matrix of pressure measurements where each column represents a time series for a particular location and each row represents a series of point measures (a map) for a given time.

2. Adjusting the matrix values to reflect that they are coming from a rounded surface

3. Subtracting from those values the seasonally adjusted mean for each location and scaling their values to produce a standard deviation of one for measurements between 1979 and 2000.

4. Finding the set of eigenvalues associated with the resulting matrix's covariance matrix

5. Identifying the largest eigenvalue in that set

This procedure obscures intuitive interpretations for non-experts, but it results in a single index that explains much of the variance in wind and pressure patterns in middle latitudes of the northern hemisphere and can be applied consistently over a relatively long geospatial time series. As I mentioned various times in this dissertation, the Case-Shiller home price index, which condenses repeat home sales data into a single value for a given geographic reason, provides a good precedent for trading based off of an index measure, developed in academia with the purpose of condensing an otherwise intractable panel dataset into a single value (Case Jr, Shiller, and Weiss, 1993).

11.3 Statistical analysis of EM-DAT disasters

Relative to ENSO, AO is characterized by:

Table 11.1: Median damage (USD m) for countries with territory above 45°N between 1960 and 2010

month	median damage for all countries above 45°N
Dec	181.108
Jan	674.379
Feb	165.211
Mar	202.054

- a short lag time between high index values and subsequent catastrophic weather
- a relatively circumscribe group of countries with the most direct exposure to AO risk (those with territory above 45°N)
- a clear seasonal window in which the index is most influential on weather (Northern Hemisphere winter)

For these reasons I chose to benchmark NOAA's monthly AO index's[1] impacts on weather disaster losses by looking at monthly damages from my enhance EM-DAT database (see chapter 2) between December to March due to extreme temperatures and storms aggregated across the countries with territory above 45°N. This gave a sample of 526 individual disasters spread across 204 months. I divided each month's aggregate damage by its monthly median from 1960 to 2010 (see table 11.1). Figure 11.1 shows damages for the AO region for all disaster types.

I performed the Augmented Dickey-Fuller Test and the Phillips-Perron Unit Root Test on both the index time series and the damage as a percentage of monthly median time series. Both tests favored the alternative hypothesis of stationarity with greater than 95 percent confidence.

The damages series showed no significant autocorrelation using a standard autocorrelation function, indicating that there is only weak interaction between the damage values of one month and the next. However, the AO index showed significant autocorrelation up to two lags. I plan to control for this dynamic explicitly in further analysis.

I defined an anomaly in the AO index as a value outside the range of -1 to 1, and ran three separate regressions - one for a high anomaly, one for a low anomaly, and one for normal conditions. In this case, the climate literature suggests that AO's high and low anomalies may cause regression lines of damages to have opposing signs (negative for low anomalies, positive for high anomalies).

The equations for those regressions are in 11.1. I selected diffuse priors for all coefficients, although I centered the priors of each slope coefficient with a slight bias toward my expectation for the sign of the coefficient. I choose diffuse priors for my AO regressions because there is relatively little published economic work on the impacts of AO to inform my inference. However, I believe these priors can be materially

[1] As of June 2013, NOAA's monthly AO index is available at `http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/monthly.ao.index.b50.current.ascii.table`.

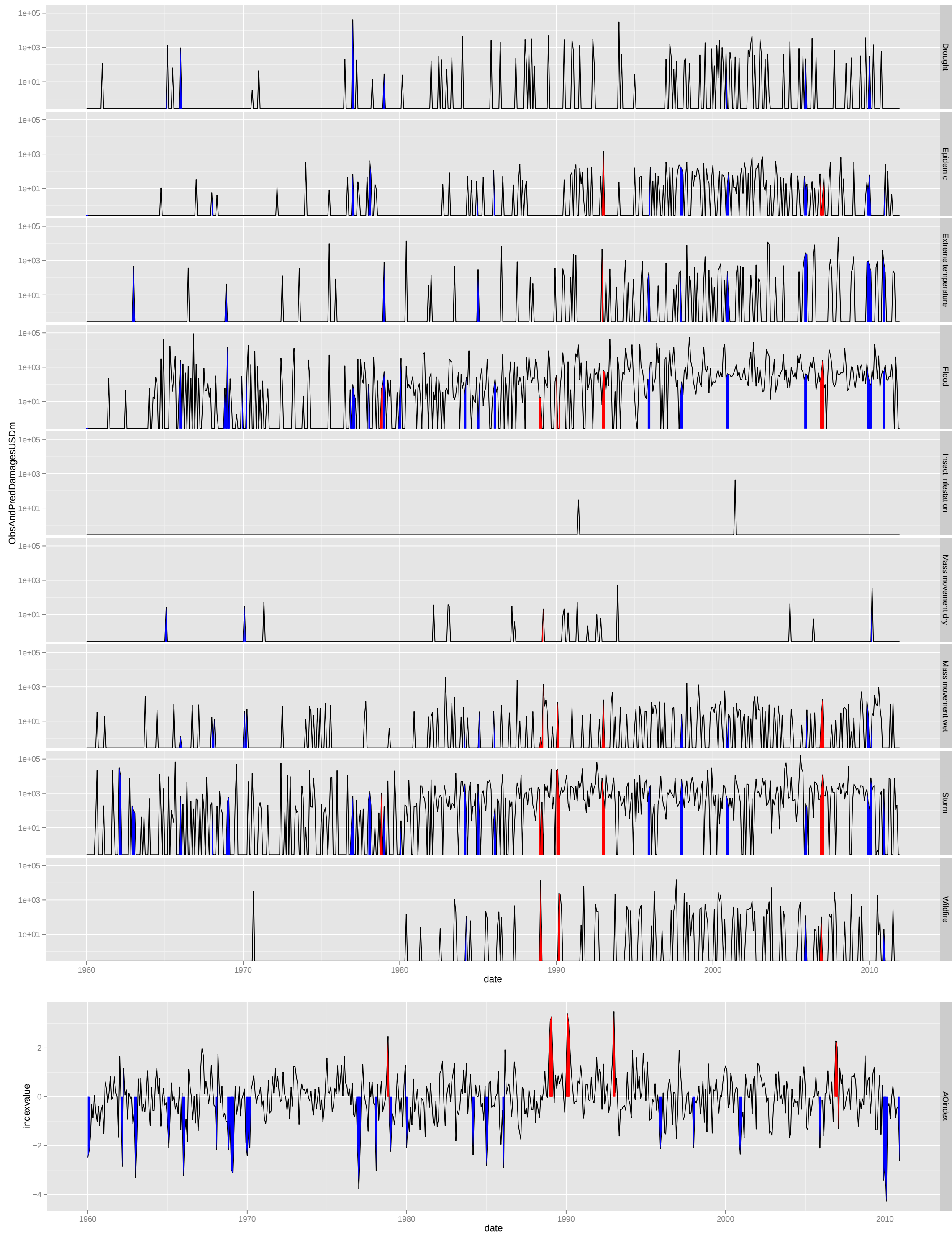


Figure 11.1: Disaster damage estimates by disaster type for countries with territory above 45 °N compared to AO index

improved by the addition of information from the climate literature, along the lines of chapter 3.

$$
\begin{aligned}
\log \text{monthly damage/median}_t &\sim \mathcal{N}(\hat{y}_i, \sigma_y^2) \\
\hat{y}_t &= a_{\text{AO phase}} \\
&\quad + b_{\text{AO phase}} * \\
&\quad \text{monthly damage/median} \\
a_{\text{low}} &\sim \mathcal{N}(1, 1000) \\
a_{\text{normal}} &\sim \mathcal{N}(1, 1000) \\
a_{\text{high}} &\sim \mathcal{N}(1, 1000) \\
b_{\text{low}} &\sim \mathcal{N}(-1, 1000) \\
b_{\text{normal}} &\sim \mathcal{N}(0, 1000) \\
b_{\text{high}} &\sim \mathcal{N}(1, 1000) \\
\sigma_y^2 &\sim \mathcal{U}(0, 100)
\end{aligned}
\tag{11.1}
$$

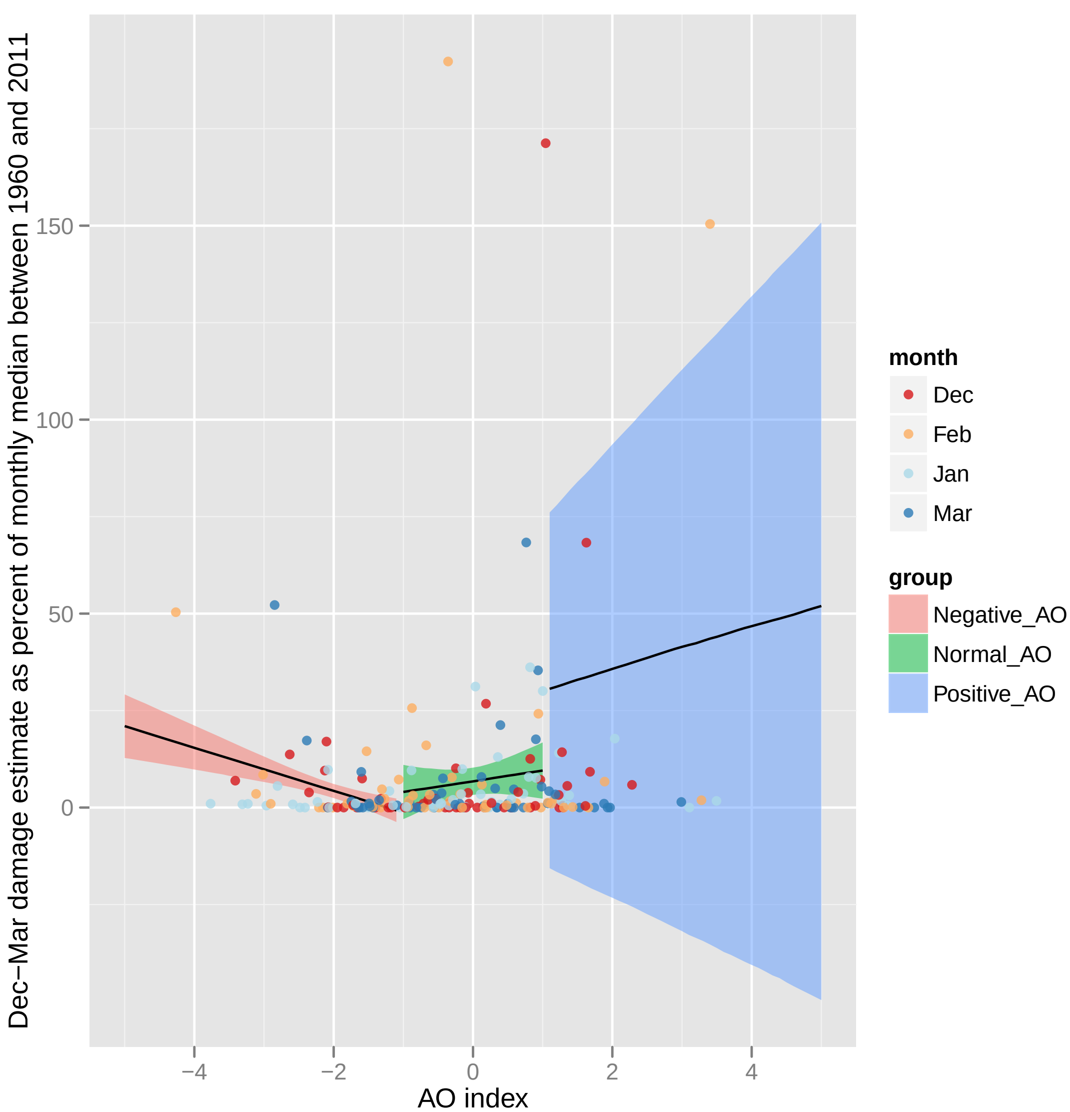


Figure 11.2: Bayesian regression analysis of damage estimates due from storms and extreme temperature during winter months predicted by AO index

Table 11.2: Diagnostics for Bayesian regression of economic damages, as a percent of the monthly median, from storms and extreme temperatures in countries with territory above 45°N from December to March on monthly AO index

positive anomaly	Observed winter months	39							
	mean	sd	2.50%	25.00%	50.00%	75.00%	97.50%	$\hat{R}$	n.eff
b[1]	24.114	18.839	-12.796	11.524	24.082	36.406	61.261	1.0016	2800
b[2]	5.239	8.690	-11.766	-0.521	5.218	10.978	22.332	1.0016	2900
sigma.y	38.441	4.659	30.786	35.125	37.963	41.265	48.909	1.0009	11000
neutral AO	Observed winter months	102							
	mean	sd	2.50%	25.00%	50.00%	75.00%	97.50%	$\hat{R}$	n.eff
b[1]	6.783	2.116	2.672	5.355	6.760	8.194	10.955	1.0015	3100
b[2]	2.833	3.770	-4.449	0.278	2.785	5.329	10.314	1.0013	4500
sigma.y	21.388	1.542	18.640	20.320	21.298	22.364	24.650	1.0009	11000
negative anomaly	Observed winter months	63							
	mean	sd	2.50%	25.00%	50.00%	75.00%	97.50%	$\hat{R}$	n.eff
b[1]	-6.854	3.375	-13.644	-9.099	-6.826	-4.620	-0.249	1.0012	6600
b[2]	-5.579	1.596	-8.730	-6.628	-5.570	-4.537	-2.403	1.0012	5800
sigma.y	8.982	0.843	7.531	8.382	8.924	9.509	10.839	1.0011	10000

Table 11.3: Damage estimates from AO anomalies of various magnitudes and months in USD m

Pr(anomaly ≥ magnitude)	magnitude	DEC	JAN	FEB	MAR
13%	-2	779.49	2902.53	711.07	869.64
7%	-2.5	1284.69	4783.71	1171.93	1433.27
3.5%	-3	1789.89	6664.89	1632.78	1996.90
1%	-3.5	2295.09	8546.06	2093.64	2560.52

The output from those regressions in table 11.2, indicate that, with 95 percent probability, the slope on the low anomaly regression is negative. That means that more extreme AO index values in the negative range are indeed associated with increased disaster damages. 0 is within the 95 percent probability interval for the slopes for positive anomaly and normal seasons. That suggests a weak or non-existent relationship between disaster damages and AO index values outside the low anomaly range. While the 50 percent probability interval of the low anomaly is distinct from those of the other regressions, the 95 percent probability intervals of the slope coefficients on all three regressions have some overlap. So while low AO anomalies produce higher damages with high probability, the impacts of low anomalies are only distinct from those associated with normal conditions with 89 probability.

To simulate the expected losses associated with extreme low anomalies in the AO index across four months studied, I drew 10,000 simulated simulated parameter value sets from the output of the low anomaly regression and applied each to the historical record of AO index, aggregating damage estimates across each season (December of year t to March of year $t+1$). Across the 10,000 simulated replays of the historical record, the mean damage due to low AO values was USD 1.6 billion in any given season. Restricting the sample to the 19 seasons (out of 51 total) with monthly index values of -2 or below, the mean damage was USD 4.6 billion. Table 11.3 shows the inferred damage estimate when I applied the low anomaly mean parameters to anomalies of various sizes and months. The table also includes the probability of seeing an anomaly of each magnitude or greater in any given month (from the empirical CDF in 11.3 and 11.4). As you can see from that estimate, individual monthly anomalies can cause damages many time greater than the annual average.

11.4 AO as a traded market

Based on those estimates, I believe that the expected hedging interest for exchange traded market on AO index risk is very large. It may in fact be larger than that for a comparable market in ENSO risk (estimated in chapter 3). Independent of specific AO conditions, the average estimated loss associated with AO is USD 1.6 billion, but the losses from a single month's anomaly can be many times that. Given the autocorrelation within the index, it is possible that over the course of an AO season, the hedging interest may growth rapidly as daily AO values climb.

Even with this clear potential hedging interest, In my opinion a few challenges set AO behind ENSO as a candidate for trading:

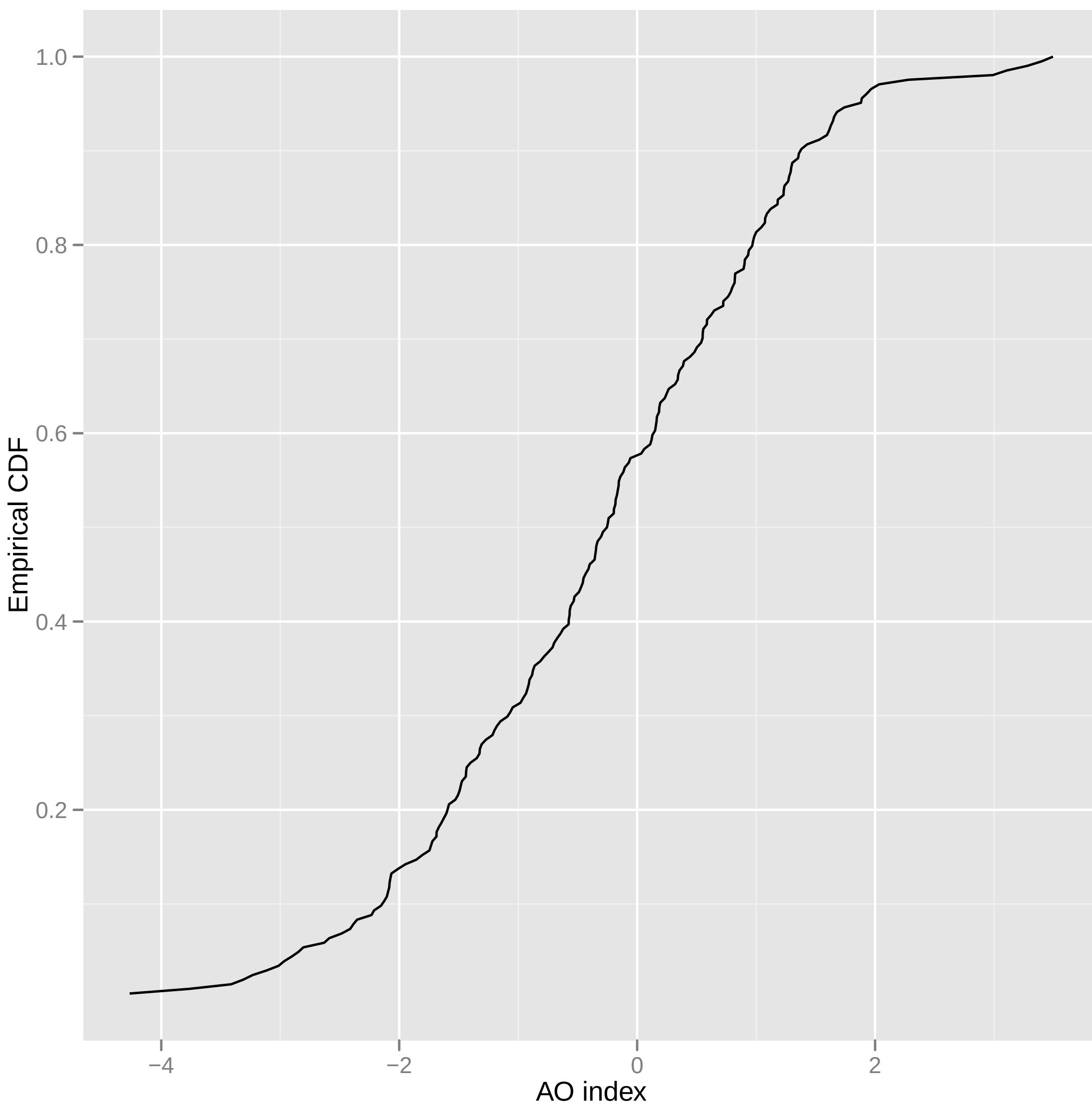


Figure 11.3: Empirical CDF of AO index during winter months 1960-2010

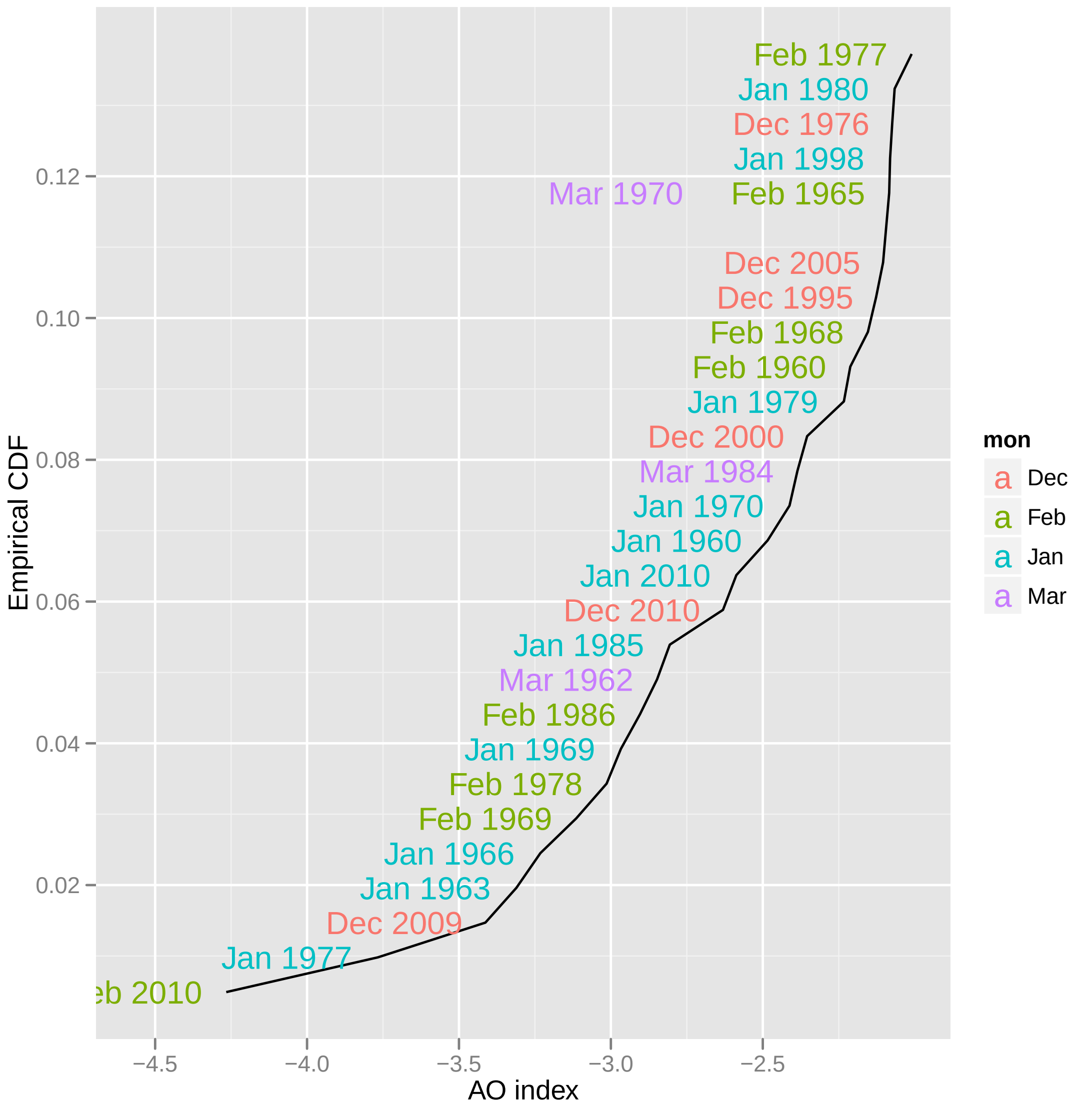


Figure 11.4: Empirical CDF of AO index during winter months 1960-2010: low anomalies

- The index itself remains highly unpredictable and markets generally favor semi-predictable risks. That link between modest predictability and liquidity was noticed as early as Working (1953). Some degree of predictability offers hedgers and speculators alike, the possibility of profiting from predictive skill.

- The basis risk on AO remains high. While my regressions suggest that AO is a strong predictor of winter disaster damage aggregated across all countries with territory above 45°N, few hedgers worry about risks spread over such a large geographic area. Before AO can be linked to the losses of specific hedgers, it will need to be decomposed or augmented to reflect the experience across smaller regions.

- Most AO risk tends to concentrate on the low side of the index. This may complicate the search for hedgers to balance the market. Unlike ENSO, AO does not create offsetting pools of risk across the globe. While many industries undoubtedly benefit from negative AO anomalies (such as ski resorts) and there may be some large groups of hedgers who actively benefit from positive AO anomalies, it may be difficult to identify enough hedging interest to roughly balance out the positions of firms and institutions looking to protect themselves from low anomalies.

These factors favor reinsurance markets as a destination for AO.

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Appendix A: Bayesian FAQ

The following is a set of frequently asked questions that introduces the Bayesian statistical methods used throughout this dissertation.

What do we call the basic statistics taught in most introductory classes?

College statistics courses generally begin with basic statistical measures, like means and variances. These are neither frequentist nor Bayesian. They are simply definitional.

However, those courses usually also include some statistical procedures for making inferences about unobservable statistical processes. Examples of those include regressions and hypothesis testing. As they are taught in most colleges, the tools in this second category come from the *frequentist* school of statistics.

What distinguishes Bayesian from frequentist statistics?

Frequentist statistics look at the likelihood of a random sample, assuming some underlying distribution for outcomes. Frequentists would ask, for example, what is the likelihood of finding that 30 out of 100 guests at a party are taller than six and a half feet, assuming that the people in the room have been randomly drawn from across America?

Bayesian statistics, by contrast, uses Bayes' Theorem (see below) to infer about the probability of the outcomes given the data. For a Bayesian an analogous question might be phrased: Given that 30 of 100 guests at a party are taller than six and a half feet, what is the most probable distribution of heights for the population from which these guests were sampled?

Can you give an example of the difference between Bayesian and frequentist statistics?

Hypothesis testing provides the best example of the difference between conditioning data on parameters (frequentists) and conditioning parameters on data (Bayesians).

When describing the relative certainty of a parameter estimate, Bayesians give a 95 percent probability interval, which has the simple interpretation of reflecting their best guess of the range in which you'll find their parameter of interest 95 percent of the time. From the Bayesian perspective, the parameter is not fixed, so 5 percent of the time the underlying parameter itself may jump out of that probability interval. Said another way, since Bayesians condition their parameter estimates on the data, they view the data as fixed and the parameter estimate as stochastic. So it makes sense to say that the mean, for example, will be in a given range 95 percent of the time, since the parameter is always popping up randomly at different values but with some clear tendencies.

For frequentists the 95 percent confidence interval often used for similar purposes has a much more tortured interpretation, one that many students (and teachers) have a hard time remembering. Frequentists imagine the world as a series of samples from a stable distribution. As those samples are only samples, sometimes their characteristics, such as means or variances, can vary wildly from the actual characteristics of the underlying process that created them. Consequently, frequentists interpret the 95 percent confidence interval as the range in which you would find 95 of the sample means for every 100 samples that you took. This is not the same as saying that the mean has a 95 chance of being in a given range, (the interpretation of the Bayesian probability interval - and the interpretation that seems most intuitive to students of statistics). For frequentists there is no variability when talking about the mean of the underlying distribution - that mean is fixed. Instead, the samples that we use to infer about the mean jump around. That is what makes statistical inference so difficult.

What defines Bayesian statistics?

At its most fundamental level all Bayesian statistics use Bayes' Theorem.

Can you state Bayes' Theorem generically?

$$P(A|B) = \frac{P(B|A)\,P(A)}{P(B)}$$

Where $P(A)$ is our *prior*, $P(B|A)$ describes the likelihood of our data given each parameter value covered by the prior, and $P(B)$ is the joint probability function describing the distribution of the data itself.

Can you give an example of Bayes' Theorem?

Applied to the problem of cancer diagnostics Bayes' Theorem is:

$$P(\text{Cancer}|\text{Postive test}) = \frac{P(\text{Positive test}|\text{Cancer})\,P(\text{Cancer})}{P(\text{Positive Test})}$$

Bayes' Theorem asks us to identify a *prior* distribution for key parameters that reflects all the knowledge we have about those parameters. In this case, the prior is the probability that anyone has a rare form of cancer, $P(\text{Cancer})$. Imagine that after receiving a positive test from the doctor, we read medical studies and find that $P(\text{Cancer}) = 0.0001$.

This prior is multiplied by a likelihood function, which describes the likelihood of our data given each parameter value covered by the prior. Let's assume that the test we took is generally accurate in diagnosing people who do indeed have this rare form of cancer, such that $P(\text{Positive test}|\text{Cancer}) = 0.8$.

While the test is accurate for people with this rare form of cancer, many people who don't have that cancer take the test. Among those people, the test incorrectly flags 1 in 100 as having cancer, such that $P(\text{Positive test}|\text{No Cancer}) = 0.01$. That means that:

$$P(\text{Positive Test}) = P(\text{Positive test}|\text{No Cancer})\,P(\text{No Cancer}) + P(\text{Positive test}|\text{Cancer})\,P(\text{Cancer})$$

$$P(\text{Positive Test}) = 0.01 * 0.9999 + 0.8 * 0.0001$$

$$P(\text{Positive Test}) = 0.010079$$

Once we divide $P(\text{Positive test}|\text{Cancer})\,P(\text{Cancer})$ by the total probability of our outcome of interest (Positive Test), then we get a measure of the probability of an outcome conditioned on the data ($P(\text{Cancer}|\text{Positive test})$). In this case, we see that because the cancer is so rare, even with a positive test, there is only a 0.8 percent chance of actually have the cancer.

Is Bayes' Theorem simply a way of logically combining individual probabilities?

The example above uses static values for variables like $P(\text{Cancer})$. But Bayes' Theorem holds just the same if you used a distribution to describe the probability of having cancer. Instead of guessing about the prior $P(\text{Cancer})$ directly, you could assume that it follows a normal distribution and guess about its mean and variance. You could then take random draws from those distributions and use those in place of $P(\text{Cancer})$ in the equation above.

Random draws from a prior distribution?...that sounds like a simulation. Does that mean that you *need* a computer for Bayesian statistics?

Bayes' Theorem is old. It was first published in its philosophical form in 1763 in a posthumously published essay by the Reverend Thomas Bayes. (The adjective Bayesian is capitalized because it refers to a person.)

However, Bayesian statistics as used in this dissertation are relatively new. Until recently it was difficult to apply Bayesian statistics to many problems because Bayesian statistical tests are often difficult to complete analytically (i.e. with algebra). But with the invention of new computer simulation techniques, it is now possible to solve just about any problem with Bayesian methods that you can with with frequentist methods. Those computer simulation techniques have helped bring Bayesian methods within the reach of any statistician.

Can you give an example of an algebraically tractable Bayesian statistics problem?

Let's say I am betting on coin flips with a friend. In most of the textbook examples of Bayesian coin flipping we begin with a relatively easy-to-work-with prior assumption about the probability of getting heads or tails. We assign our prior a uniform distribution or a beta distribution, which both behave very nicely with a Bernoulli likelihood function (which is generally what we'd use to tell us how likely we are to get a given number of heads given some number of flips).

In fact, even though Bayes' theorem asks us to multiply the two (likelihood and prior) and divide them by the integral of their joint probability, uniform and beta priors play so nicely with Bernoulli likelihoods that we can skip all that math by applying some simple numerical shortcuts and ending up with a posterior - a distribution for the underlying parameters conditioned on the data.

Priors that allow for mathematically simple *updating* (conditioning outcome probabilities on the data) are called *conjugate priors*. Conjugate priors are, in fact, relatively rare, even though most basic texts on Bayesian statistics introduce Bayesian updating with their help.

Can you give an example of a algebraically intractable Bayesian statistics problem?

Suppose our prior is not so easy to work with: I am betting on coin flips with a friend, but I know this friend to be mischievous, so I believe that there is a decent chance that the coin is biased towards heads or tails, but I don't know which one and I don't know the extent of the bias.

Hence I might easily have a prior that is bimodal with all sorts of quirky attributes between the two modes. That prior ($P(A)$) would not lend itself nicely to multiplication with a Bernoulli likelihood function ($P(B|A)$) and the operation would be even more complex when it comes time to integrate the likelihood of a given number of heads over the entire range of our prior (i.e. finding $P(B)$). With a prior that is so difficult to work with, we would not be able to use simple numerical tricks or any tractable algebra. In this case we would need to integrate numerically - simulating draws from our contingent distributions and adding up the resulting probabilities.

Can you give an example of a really algebraically intractable Bayesian statistics problem?

Take the above example one step further and imagine that you have what's called a *multilevel model* also known as a *hierarchical model*, where the distribution you place on your friend's rigging of the coin is actually the result of a combination of other distributions: if he's recently won the lottery he may be less included to bias the coin, if he recently saw Washington's head on a dollar bill he may be subconsciously anchoring on heads, etc. Each of those factors is now a parameter in the equation that defines the parameters of the original coin flip distribution (i.e. draws from each of those distributions become mathematical inputs into the equation that defines our prior beliefs about the bias of that coin).

It is very hard to use closed form equations for the multidimensional distribution that results when you make one parameter contingent of the value of many others, each of which may have its own difficult-to-describe distribution.

Why has there been so much recent interest in Bayesian statistics?

By the late 1980s, random number generators were common tools, built into even basic retail software. But the algorithms behind these random number generators pertained to well-known distributions like the uniform. There was no generic algorithm for generating representative samples from a multidimensional and hard-to-describe joint distribution. Consequently, Bayesian statistics remained obscure.

That problem was solved for Bayesians with the rediscovery of Gibbs sampling, an algorithm to do just this type of random sampling. The algorithm itself is technically a special instance of the Metropolis-Hastings algorithm, which describes how to jump around the space of a joint distribution such that you explore values in far-flung parts of the distribution, but spend most of your time exploring parts of the distribution that are successively more probable. This series of sampled points, each related to the last through the Metropolis-Hastings algorithm is a Markov Chain, or a probabilistically linked chain of values.

So how does Gibbs sampling work?

In his book *Doing Bayesian Data Analysis: A Tutorial with R and BUGS* John Kruschke gives an excellent example of how a Metropolis-Hastings algorithm works (Kruschke and John, 2010). (I recommend the book to anyone who wants a practical and well-thought-out introduction to Bayesian statistics.) I will rehash that example below:

Imagine that you're a door-to-door saleswoman, assigned the Aleutian Islands as your sales region. The Aleutian Islands are a long archipelago (a chain of small islands) off the coast of Alaska, so you need a boat to get from one to the other. Your employer is very cheap so they've only given you a boat large enough to make the trip from one island to the next without stopping to refuel. This means that everyday you essentially have to decide whether you are going to the next island in the chain to your east or your west. Of course, as a saleswoman you want to visit the islands with the largest populations. Unfortunately, your employer has also cut corners in doing reconnaissance along your route: they haven't provided you with the populations of any of the islands. Since the islands are so isolated the only way you can get population information for an island is by asking at the town hall of that island or its immediate neighbors.

Your sales strategy could be to always move to the next island in the chain as long as that island has a higher population than the one you're on. But that potentially means that you could get stuck at a local maximum - an island with a larger population than either of its neighbors, but not the highest population overall. Thanks to that possibility, it makes sense to include in your sales strategy some exploration - some room to visit islands with lower populations than the one you're currently on. This desire to explore the island chain must always be balanced with the need to spend time selling on those islands with the largest population. So what rule (or algorithm) will allow you to have the best balance of exploration and exploitation?

As Kruschke illustrates so well with graphics and equations, the optimal rule for island hopping is one in which you:

1. Randomly choose to evaluate a move to the east or west.
2. Decide to take that move based on another random draw for which the probability of rejecting the move (and staying put) is a function of the relative populations of the proposal island to the current island.
3. Repeate many, many times.

This *rejection sampling* is a one dimensional illustration of the Metropolis-Hastings algorithm. If you island hop for long enough according to this algorithm, you will eventually end up visiting all the islands in proportion to their populations.

Metropolis-Hastings is an example of a algorithmic family called *Markov Chain Monte Carlo*. The "Monte Carlo" part comes from its reliance on pseudo-random number generation, the "Markov Chain" part relates to the fact that the algorithm moves though the probability density space one jump at a time, and the only thing that matters for your next jump is where you are now. In other words, when you decide on your next move, it doesn't matter which island you visited two hops ago. Sequences in which the only historical information that matters to your next move was your immediate last move are called Markov chains.

While Markov Chain Monte Carlo describes a class of algorithms including Metropolis-Hastings, Gibbs sampling, the specific algorithm favored in Bayesian statistics, is a specific instance of Metropolis-Hastings. In Gibbs sampling, the saleswoman analogy starts to breakdown: the saleswoman gets a promotion to the rockies, and she now has to decide whether to move north, south, east, or west, as well as the elevation she wants to target. Furthermore, to decide what her next move is she has to take into account not just population but also a host of other factors such as average household wealth.

Gibbs sampling essentially moves the saleswoman across a multidimensional space by changing one dimension value at a time. Unlike our example, there is no rejection of the next proposed move. With Gibbs sampling you simply run multiple versions of your algorithm, without rejection, jumping to new values one parameter at a time. You know that you have *converged*, meaning that you are getting sampling values whose summary statistics are actually indicative of the main density areas in your underlying distribution, when all of those *chains* or independent runs of the same random hopping algorithm start to give values in the same ballpark.

Can you give an example of a Bayesian regression?

The following example comes from Chapter 16 of Gelman and Hill (2007). The code is for the Bayesian statistics program BUGS[2]. The original code is available at Gelman and Hill (2007)'s website:

[2] In my dissertation, I use a close relative of BUGS, called JAGS.

- http://www.stat.columbia.edu/~gelman/arm/.

Imagine that you are trying to run a regression in which corn yield is predicted by fertilizer applications. You begin with a vector of crop yield measurements which we'll call y. You also have a vector of corresponding applications of a certain fertilizer which we'll call x. So y is your dependent variable and x is your explanatory variable.

Below that problem is specified in the language of BUGS:

```
model {
  for (i in 1:n){
    y[i] ~ dnorm (y.hat[i], tau.y)
    y.hat[i] <- a + b*x[i]
  }
  a ~ dnorm (0, .0001)
  b ~ dnorm (0, .0001)
  tau.y <- pow(sigma.y, -2)
  sigma.y ~ dunif (0, 100)
}
```

First we tell BUGS that we are about to specify a model.

```
model {
```

Next we set a for loop that will define a relationship underlying each individual observation (subscripted i with a total of n observations) in our data set.

```
for (i in 1:n){
```

Each observation y[i] is distributed around an average value (y.hat[i]) which is predicted by x[i], with standard deviation sigma.y. That is to say, that we are conceptualizing all the points (x[i],y[i]) in the sample as a deviation from our regression line with points (x[i],y.hat[i]). How much those points deviate from that regression line is represented by a normal distribution (signified by the function dnorm) with standard deviation parameter sigma.y.

BUGS specifies normal distributions using precision tau.y, rather than standard deviation sigma.y Statistical precision is just the inverse of the variance.

```
y[i] ~ dnorm (y.hat[i], tau.y)
```

The regression line represented by the points (x[i],y.hat[i]) can be represented in point-slope form using the intercept a, and the slope b.

Note the difference here between the symbol <- that we use to indicate a definite relationship and the symbol $\sim$ that we used before to indicate a distributional relationship.

y.hat[i] has a stable linear relationship to x[i]. If you have values for a, b, and x[i] then you deterministically can get the corresponding value of y.hat[i].

In contrast, the relationship between y[i], the actual crop yield measurement, and y.hat[i], your best guess at the yield given what you know about fertilizer application, is probabilistic. It is anchored by a regression, but any given measurement of crop yield may vary around that regression.

```
y.hat[i] <- a + b*x[i]
```

We have now specified the model that describes all of the individual points we'd like to model, so we close the brackets on our for loop.

```
  }
```

But there are still a few parameters that are in our model that we need to specify. These are our prior distributions. Our priors do not change from observation to observation so they are defined outside of the for loop we just closed.

As I discussed above, Bayesians imagine that parameters are random, while frequentists believe that samples are random. a and b are parameters so we will assume that they follow some random distribution. Here, we assume that distribution is a normal with mean 0 and a very wide standard deviation (precision = .0001).

Note here that priors in a Bayesian estimation are always distributional, thats why we use $\sim$ instead of <-.

```
  a ~ dnorm (0, .0001)
  b ~ dnorm (0, .0001)
```

The final prior we need to specify is for the standard deviation of the points y[i] as they vary around their regression-defined means y.hat[i]. This distribution, like those of a and b, is not going to change from observation to observation, so it is outside our for loop. Standard deviations cannot go below zero, so we use a uniform distribution (noted by the function dunif) bounded between zero and one hundred.

Since most people aren't used to thinking in terms of precision, as BUGS demands, we are actually going to set a prior for the standard deviation of the points around the regression line, sigma.y. But since BUGS needs precision values, we will assign those standard deviation values to their corresponding precision values. This relationship between precision and standard deviation is just a simple deterministic rule so we use <- in our code.

```
  tau.y <- pow(sigma.y, -2)
  sigma.y ~ dunif (0, 100)
```

Finally, we close the model itself using a closing bracket.

```
}
```

What do the results of that model look like?

When we run this model using data from Gelman and Hill (2007) we get the following output:

```
 3 chains, each with 500 iterations (first 250 discarded)
 n.sims = 750 iterations saved
          mean  sd   2.5%    25%    50%    75%  97.5% Rhat n.eff
a           1.3 0.0    1.3    1.3    1.3    1.3    1.4    1   100
b          -0.6 0.1   -0.7   -0.7   -0.6   -0.6   -0.5    1    79
deviance 2250.0 2.4 2247.2 2248.2 2249.4 2251.0 2256.1    1   340
sigma.y     0.8 0.0    0.8    0.8    0.8    0.8    0.9    1   420

For each parameter, n.eff is a crude measure of effective sample size,
and Rhat is the potential scale reduction factor (at convergence, Rhat=1).

DIC info (using the rule, pD = var(deviance)/2)
pD = 2.9 and DIC = 2252.8
DIC is an estimate of expected predictive error (lower deviance is better).
```

Ignore the actual coefficient values for the moment and look at their form. They are all given in distributional form, with estimates for various quantiles. Each parameter is a random variable.

How would the results of that model look if it were run as frequentist regression?

Here is the output for the same regression run using the standard frequentist least squares regression.

```
lm(formula = y ~ x)
            coef.est coef.se
(Intercept)  1.33     0.03
x           -0.61     0.07
---
n = 919, k = 2
residual sd = 0.82, R-Squared = 0.07
```

How do the Bayesian and frequentist regressions compare to one another?

As you can see, the median estimates for the most important coefficients are roughly equivalent to those from the frequentist estimation. The residual standard deviation is also roughly equivalent to the median estimate of `sigma.y`. The similarity between the two estimates comes from a confluence of facts about this particular model:

- The Bayesian analysis used *uninformative* priors. Uninformative priors are priors that cover the entire space in which the parameter in question could reasonably be found and also provides little information about where in that space the actual parameter might be. So in this case we used normal distributions with very wide standard deviations and, for parameters that must be positive, uniform distributions. Making a parameter too uninformative (i.e. giving the parameter a huge standard deviation) can be a hindrance to convergence of the model.

- There are a relatively large number of data points. As each successive data point is fed into the model, the resulting posterior distribution for each parameter becomes the prior distribution for that parameter as the next data point is fed in. This means that as the amount of information fed into the model through Bayes' theorem increases, the influence of the data dwarfs that of the priors. In this case, that makes the frequentist estimate, based entirely on the data, look very similar to the Bayesian estimate.

If we had strong prior convictions about the coefficients of the regression (which we incorporated into the prior) and relatively few data points with which to update the model, then the influence of the prior may well drive our Bayesian model coefficients to look different than those of our frequentist estimate.

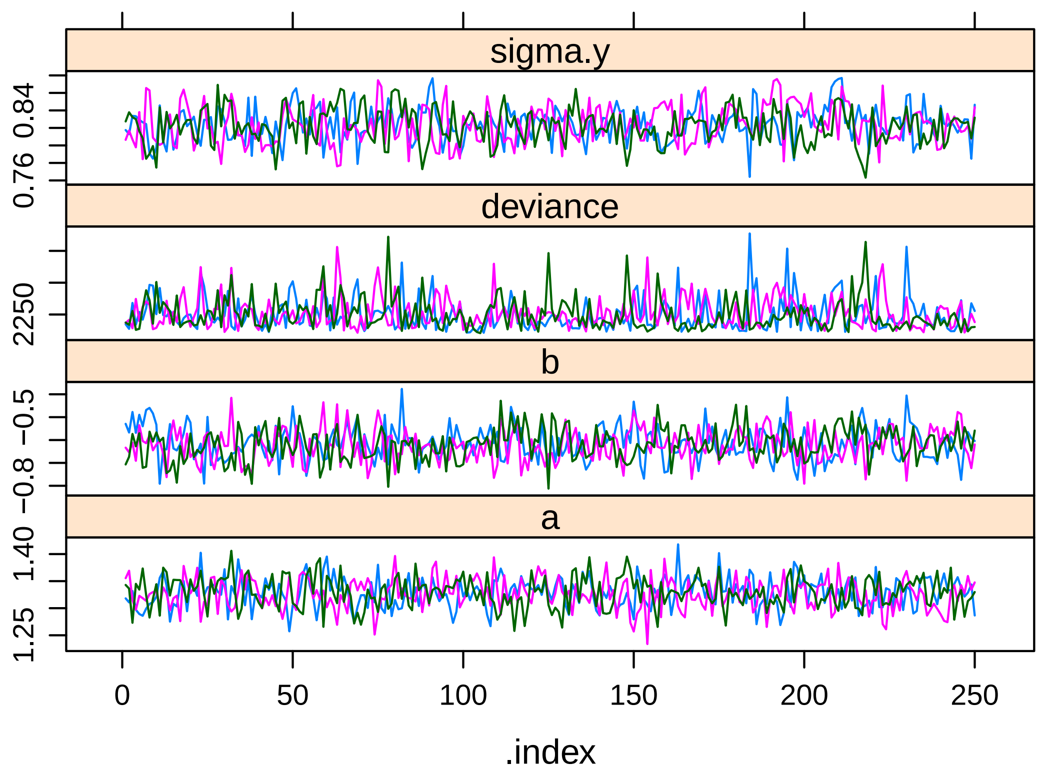
What are all those other output values on the Bayesian regression that we never see on frequentist regressions?

While there are analogous Bayesian statistics for many of the major diagnostics that you would want from a frequentist analysis (such as R^2), Bayesian statistical estimates generally require us to interpret a few additional diagnostics that you don't find in frequentist estimates. These are generally related to the fact that Bayesian estimates use simulation techniques that must *converge*. Convergence as we discussed earlier refers to the point at which the moments of the simulated distributions roughly match those of the actual underlying distribution and are no longer heavily influenced by quirks in the simulation algorithm. In the case of a Gibbs sampler, convergence refers to the point at which the various simulation chains start behaving similarly. At the end of chapter 16 Gelman and Hill (2007) walks step-by-step through those additional diagnostics, so for this introduction, I will just mention the most important statistic, $\hat{R}$ or `Rhat` in the above output. This value is a measure of the degree of convergence between the chains in the simulation - technically it is the "…square root of the variance of the mixture of all chains, divided by the average within-chain variance" (Gelman and Hill, 2007). The closer the value is to 1, the greater the degree of convergence in the model. Gelman suggests that we not consider our model converged until we see values of $\hat{R}$ below 1.1 for each estimated value.

If Bayesian regressions involve simulation and random number generation, where is the simulation output?

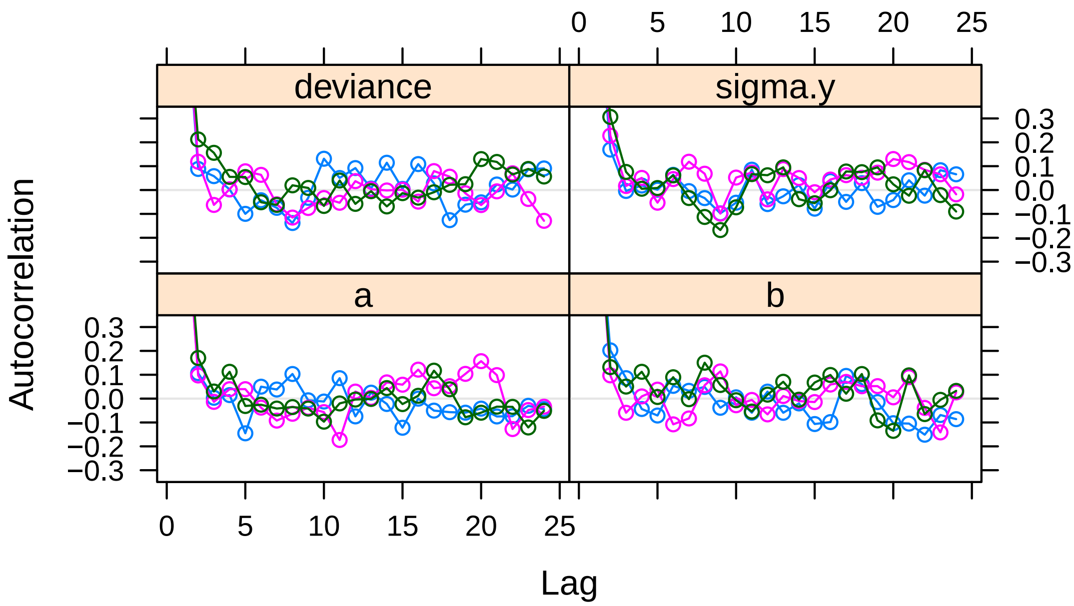
In addition to the $\hat{R}$ statistic, Bayesians use various graphs to monitor convergence in their models. The most important such graphics are the actual posterior estimates that the simulation produces, autocorrelation functions showing the relationship between successive simulated values, and the density plots for posterior estimates. In `R`, these plots are accessed through the `coda` package in R. Below are the plots for our regression:

Figure 1: Parameter simulations from the posterior distribution



In figure 1, you can see that the various chains (different colored lines) are behaving more or less in the same fashion. Their spikes (draws from the tail of the distribution) are roughly of the same magnitude and settle on similarly high density regions. This means that chains with random paths are giving similar hints about the characteristic of the underlying distribution - a strong indication of convergence. Given enough time to run and an underlying distribution which is not too difficult to summarize, then you would get reasonable guesses about the characteristics of population from any single chain.

Figure 2: Autocorrelation function for parameter simulations from posterior distribution



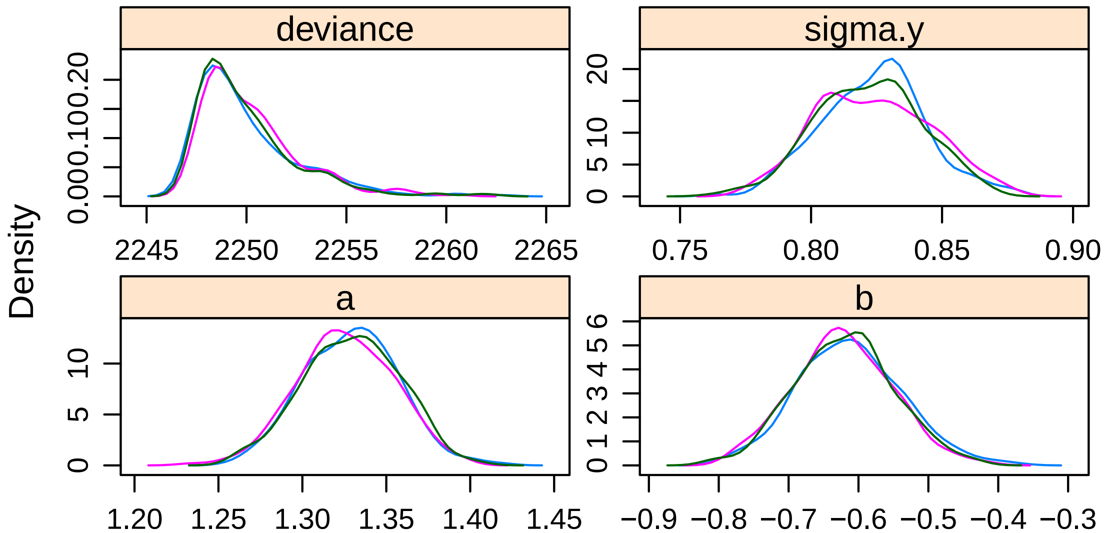
In figure 2, you can see that none of the chains show high levels of autocorrelation after the first lag. So where the simulation is now is a factor in the next drawn value, but it is not very predictive of where the simulation will be a few draws into the future. This is a good indication of the randomness of the draws produced by Gibbs sampling.

Finally, we have the density plots for the various estimates in figure 3. All show roughly the same tendencies, although there is some variation, especially for the parameter `sigma.y`.

Where's the p-value in the Bayesian regression?

The one important statistic that you will not see in the Bayesian regression output above is a p-value, or any measure of statistical significance for our estimated param-

Figure 3: Densities of parameter posterior distributions



eters. To be sure, Bayesian analysis easily facilitates the class of inference presented by those measures - telling you if a given parameter is, according to the model, not zero. But as discussed above (see the hypothesis testing discussion above), the interpretation of uncertainty within Bayesian and frequentist models are very different such that certain measures of that uncertainty, such as the p-value, have no place in Bayesian estimation. P-values tell us, assuming we have 100 random samples of a given population, how many would give us parameter estimates that are not zero. Since the sample is fixed in Bayesian analysis we have no p-values. Instead we have a direct estimate of the underlying parameter values through simulation. We don't need to look at difficult-to-interpret statistics such as the p-value to make inferences about the underlying parameter - we just look at the simulation output.

Instead of p-values, Bayesians simply look at the distribution of their key parameters, asking: Where does zero fall in those distributions? In the example above, the quantiles indicate that it is very improbable that any of our parameters is equal to zero. But even if, for example, our estimate of the intercept parameter had a value of -0.5 as the 2.5th quantile of its simulated output and a 97.5th quantile at 1.5 then we would not say that the estimate is statistically insignificant - only that parameter estimates show that 0 is within the 95 percent probability interval, so we fail to reject the null hypothesis that the estimate is equal to 0. That may sound like semantics, but especially when you have a small sample size, you may get relatively important information from your simulations of the posterior distribution, whereas a frequentist estimate, seeded with the same data, might have been deemed insignificant due to its low p-value. To be sure, Bayesian econometricians still have a strong incentive to reject the null hypothesis of parameter estimates equal to zero (or keep it in cases where that result is more impressive) but the use of simulated values from a posterior begs for deeper interpretation rather than the fatalistic dismissal or embrace of a result based on its p-value.

What types of problems are well-suited to Bayesian analysis?

I also preferred Bayesian methods in this dissertation for four primary reasons:

1. Ease of interpretation - As I've discussed above, Bayesian estimates are directly interpretable in terms of probabilities. This makes hypothesis testing simple and intuitive. In chapter 6, this allows me to quickly and easily compare many estimates of the probabilities of contracts moving between levels of liquidity.

2. Priors - Bayesian methods allow researchers to incorporate knowledge that may simply be left out of their datasets, but should be included in their analysis. For example, in chapter 3 I knew that my dataset was missing important disasters related to ENSO. I also had previous estimates of the economic impacts of those disasters. So, rather than knowingly present a biased regression (i.e. running my models without those disasters) I incorporated some of the information from those studies into my regressions through my priors.

3. Missing data imputation - Another big advantage of Bayesian analysis based on Gibbs sampling is the relative ease of *imputing missing data*, the process of inferring missing data values from other variables. In chapter 2, I needed to use parameter estimates to fill in missing data. That technique is called *bootstrapping* and is a relatively advanced econometric operation in frequentist statistics. In Gibbs sampling however, missing data are imputed seamlessly, without any special operations.

4. Non-stationarity - Bayesian methods do not assume that key parameters are stationary across time. Each parameter follows a distribution and if, for example, the values of that parameter are creeping up over time, then that simply widens its distribution. In frequentist statistics, by contrast, we assume that parameters are stationary. If they are not, we have to explicitly correct for that dynamic. In chapter 4 I looked at the distribution of sea surface temperatures that may be rising gradually thanks to climate change. By using Bayesian methods, I could estimate prices for risk protection against those temperatures without making explicit assumptions about the influence of climate change.

Appendix B: Lifecycle Appendix

Table 1: Priors on transition between volume states - with annual trading volume state in year t denoted by row, trading volume state in year t denoted by column

volume level	0	1	10	100	1000	10^4	10^5	10^6	10^7	10^8
0	0.78	0.14	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
1	0.16	0.63	0.14	0.01	0.01	0.01	0.01	0.01	0.01	0.01
10	0.01	0.16	0.63	0.14	0.01	0.01	0.01	0.01	0.01	0.01
100	0.01	0.01	0.16	0.63	0.14	0.01	0.01	0.01	0.01	0.01
1000	0.01	0.01	0.01	0.16	0.63	0.14	0.01	0.01	0.01	0.01
10^4	0.01	0.01	0.01	0.01	0.16	0.63	0.14	0.01	0.01	0.01
10^5	0.01	0.01	0.01	0.01	0.01	0.16	0.63	0.14	0.01	0.01
10^6	0.01	0.01	0.01	0.01	0.01	0.01	0.16	0.63	0.14	0.01
10^7	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.16	0.63	0.14
10^8	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.16	0.76

Figure 4: Transition matrix for Markov model of derivatives contract moving between states of annual trading volume by exchange - part 1: transitions given annual volumes ≥ 0 and < 10

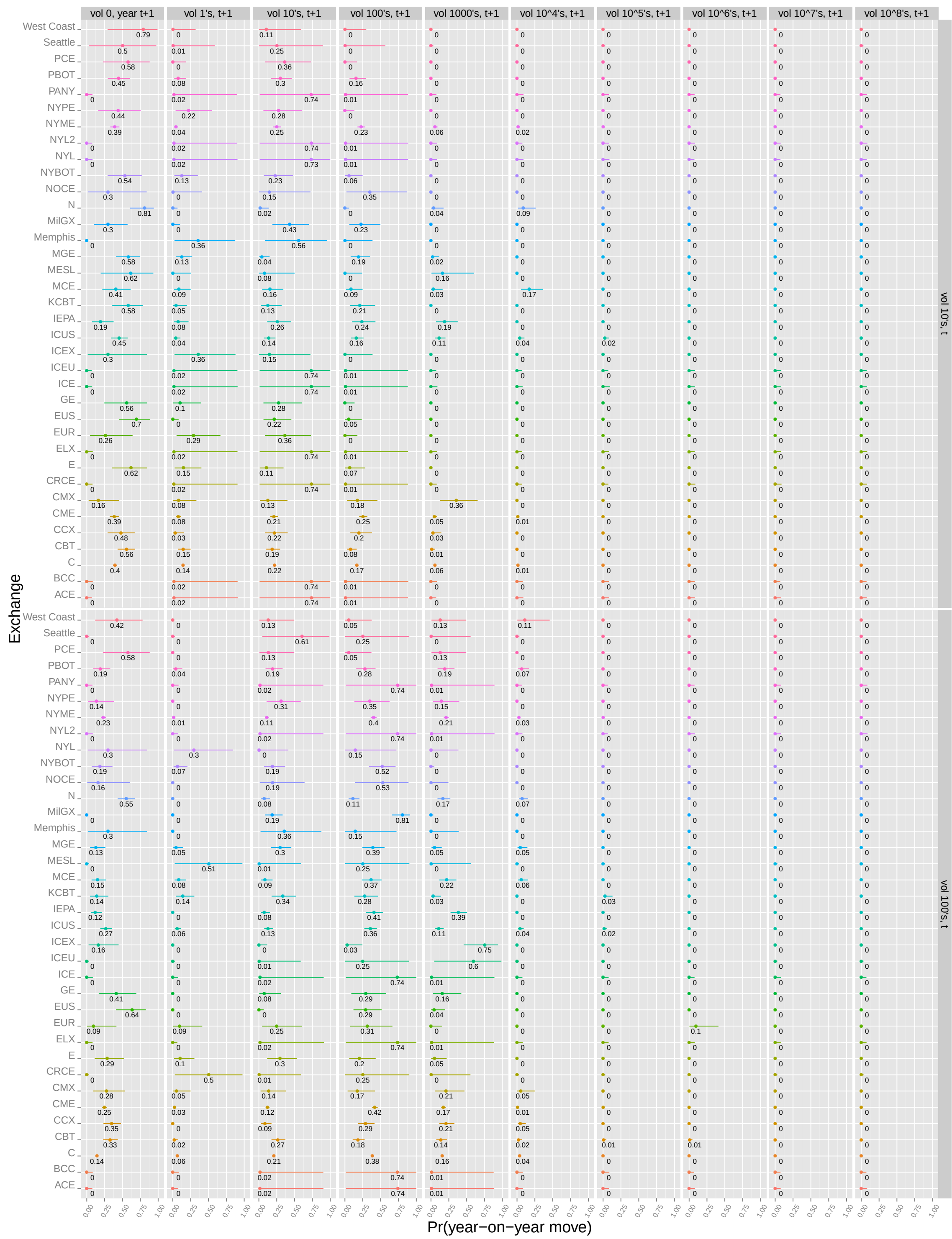


Figure 5: Transition matrix for Markov model of derivatives contract moving between states of annual trading volume by exchange - part 2: transitions given annual volumes ≥ 10 and $< 1,000$

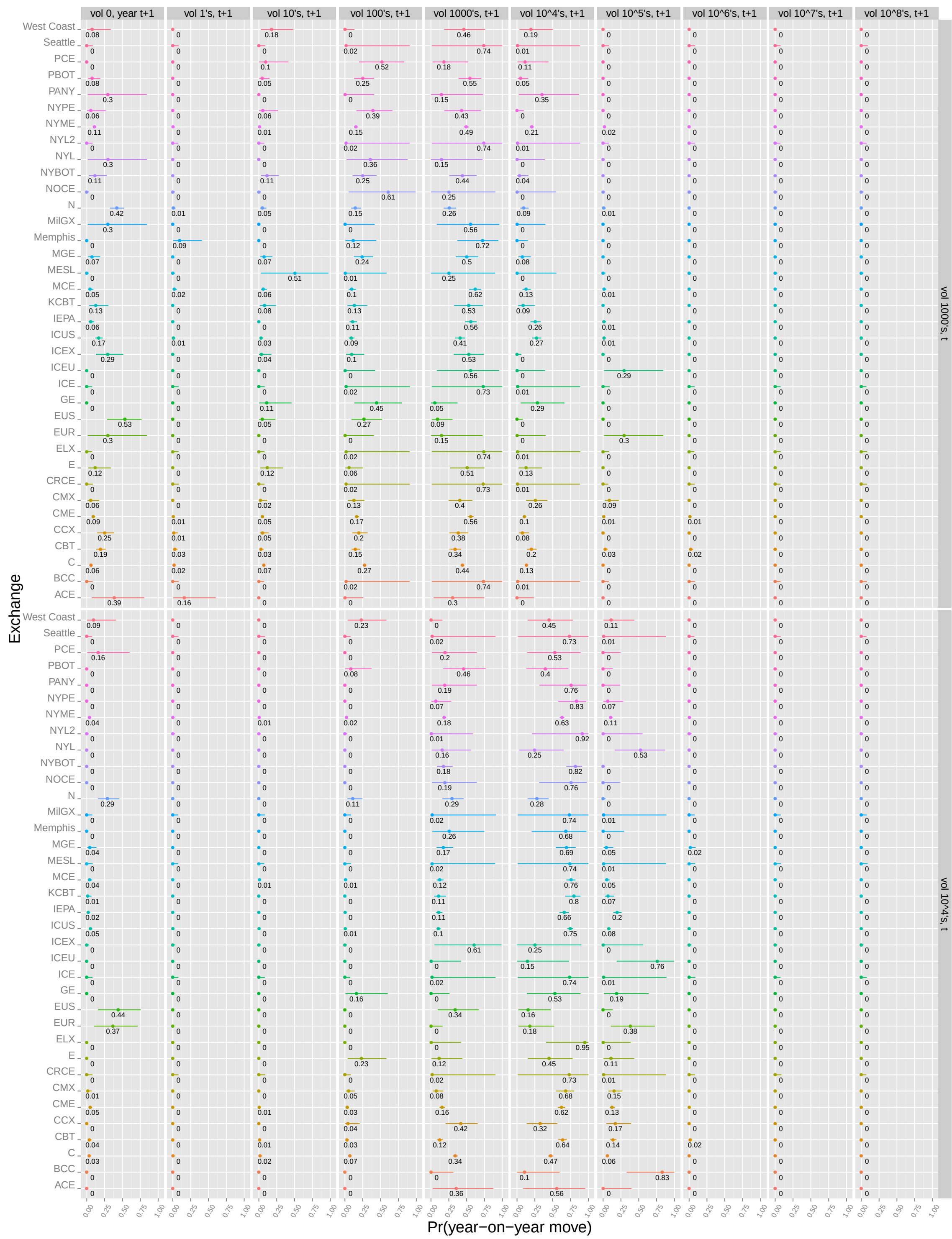


Figure 6: Transition matrix for Markov model of derivatives contract moving between states of annual trading volume by exchange - part 3: transitions given annual volumes ≥ 1000 and $< 10,000$

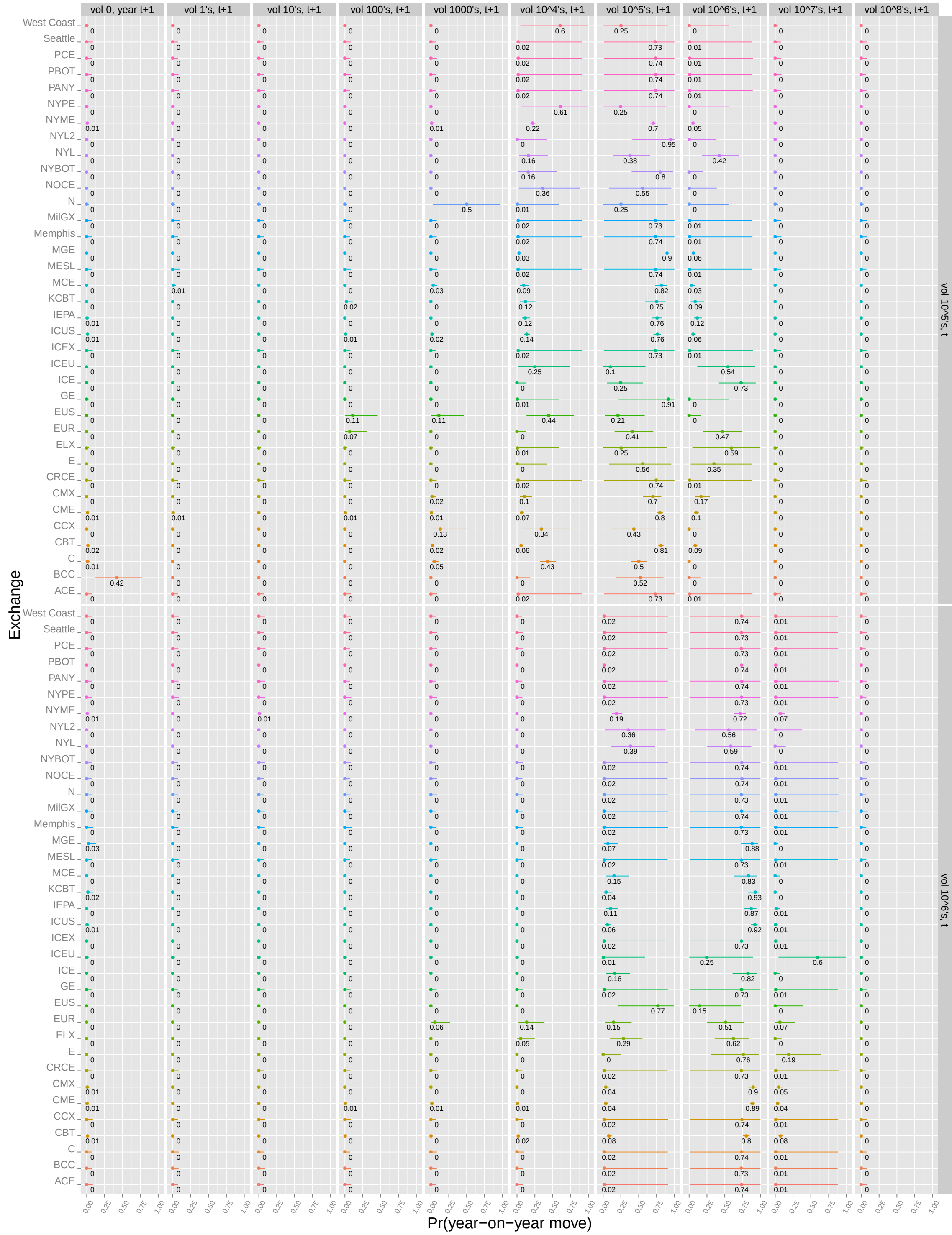


Figure 7: Transition matrix for Markov model of derivatives contract moving between states of annual trading volume by exchange - part 4: transitions given annual volumes $\geq 10,000$ and $< 1,000,000$

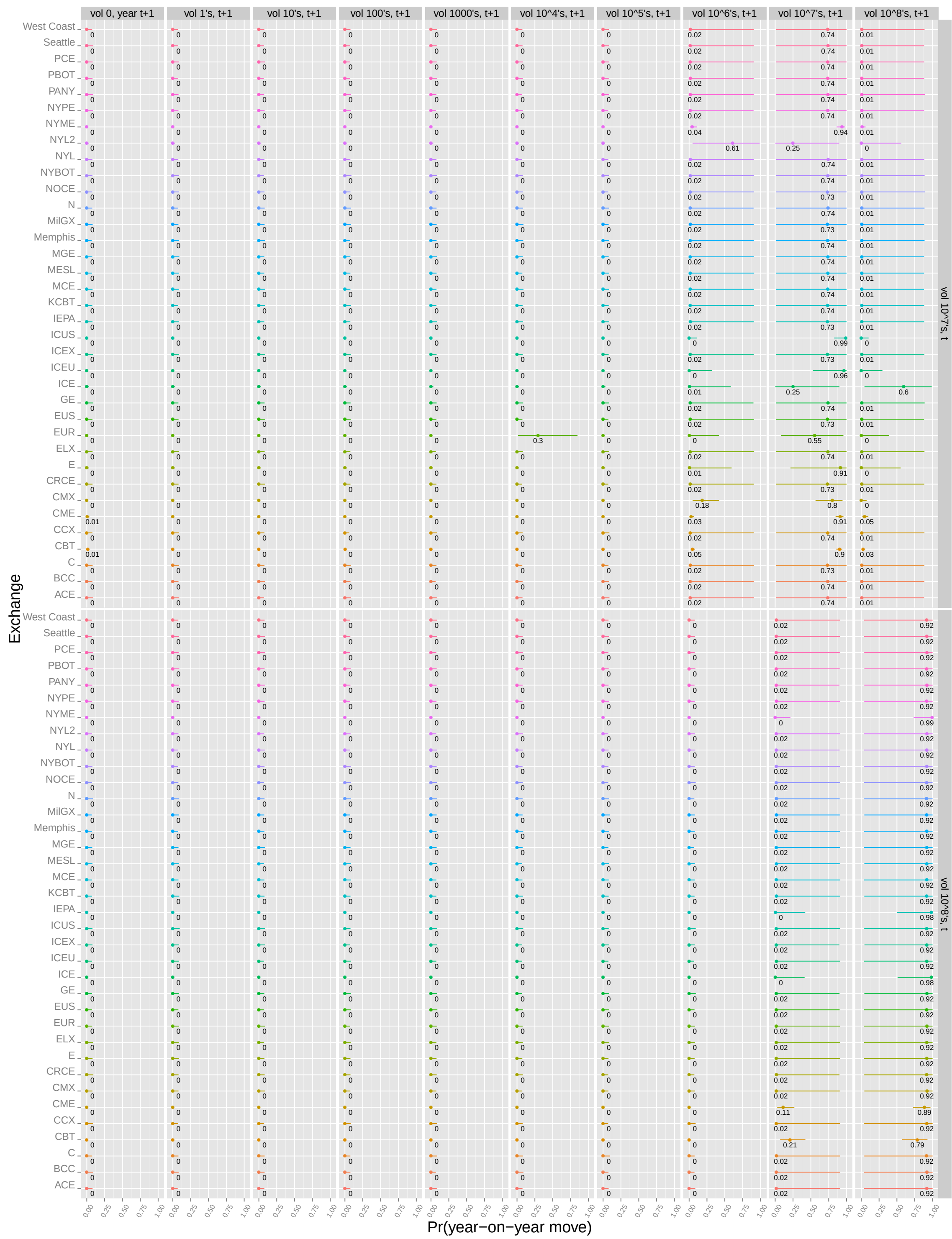


Figure 8: Transition matrix for Markov model of derivatives contract moving between states of annual trading volume by exchange - part 5: transitions given annual volumes $\geq 1,000,000$

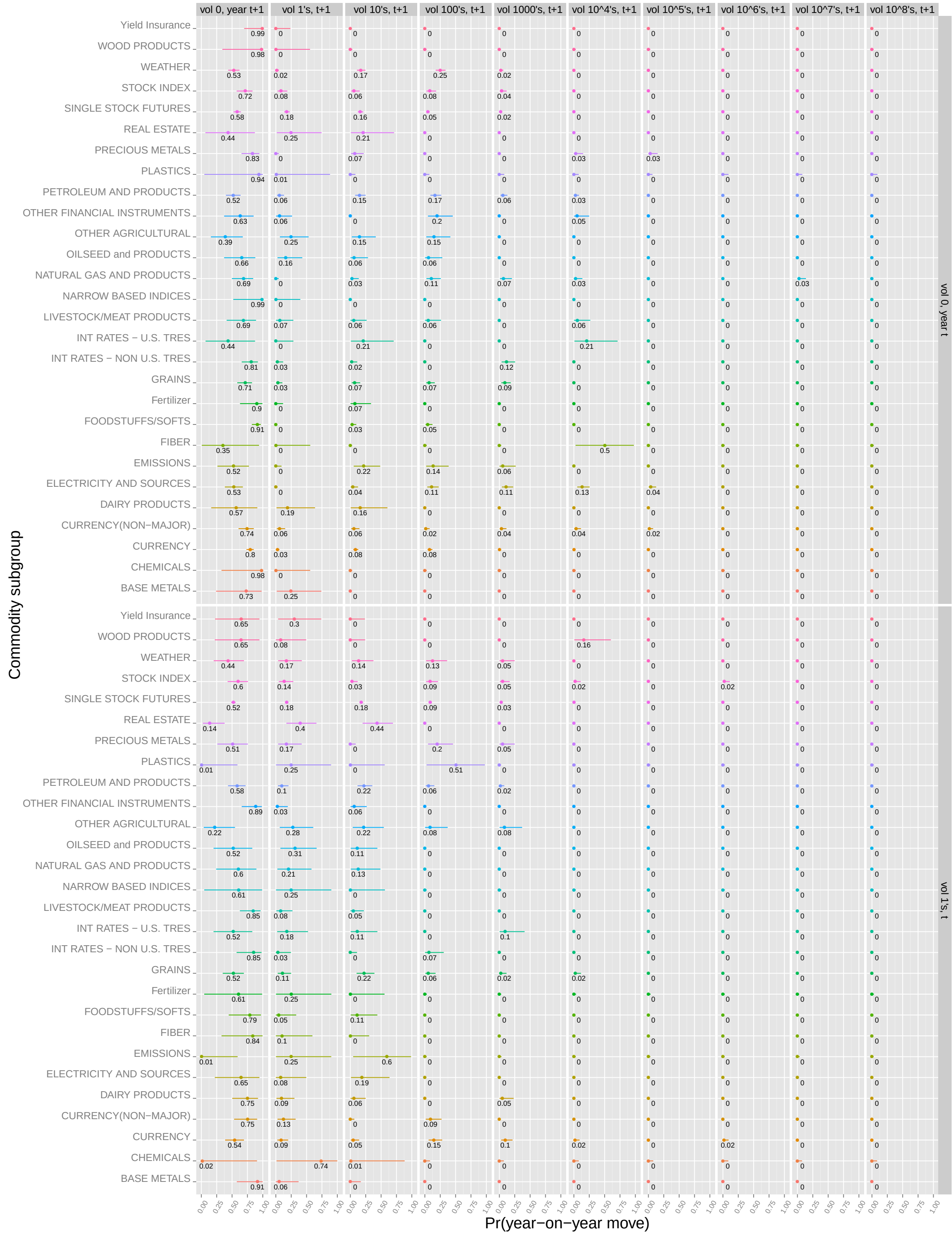


Figure 9: Transition matrix for Markov model of derivatives contract moving between states of annual trading volume by product type - part 1: transitions given annual volumes ≥ 0 and $< 10,000$

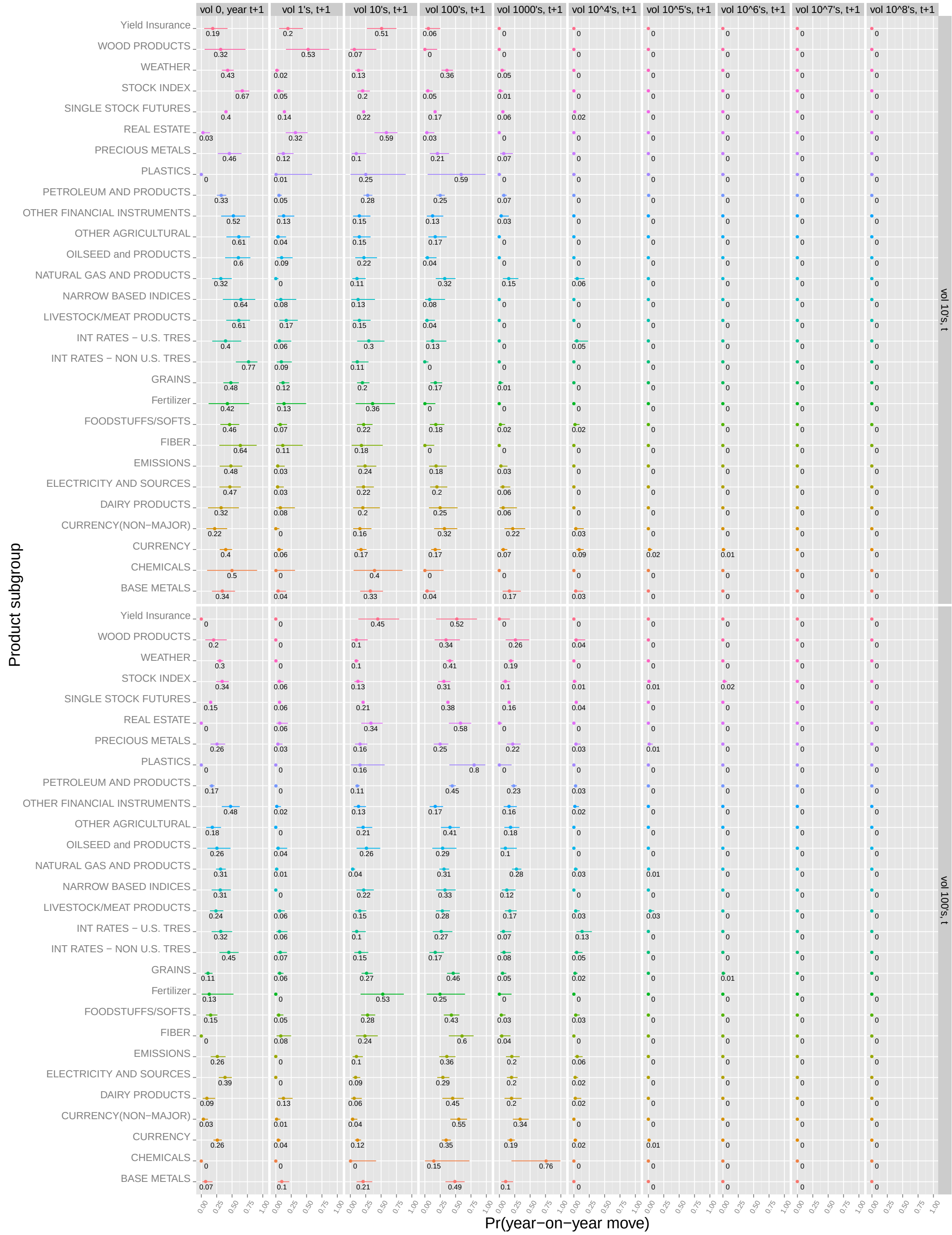


Figure 10: Transition matrix for Markov model of derivatives contract moving between states of annual trading volume by product type - part 2: transitions given annual volumes ≥ 10 and $< 1,000$

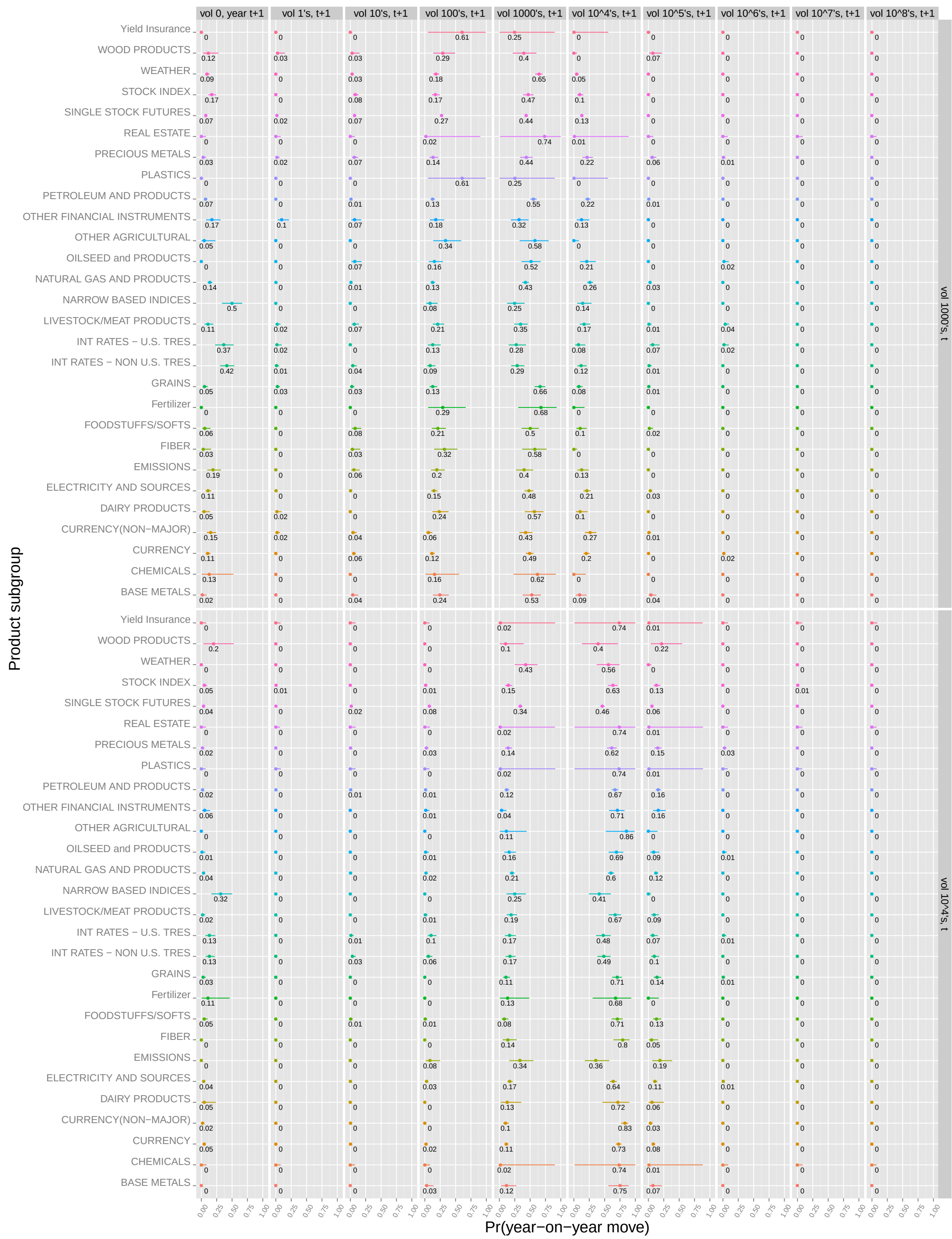


Figure 11: Transition matrix for Markov model of derivatives contract moving between states of annual trading volume by product type - part 3: transitions given annual volumes ≥ 1000 and $< 10,000$

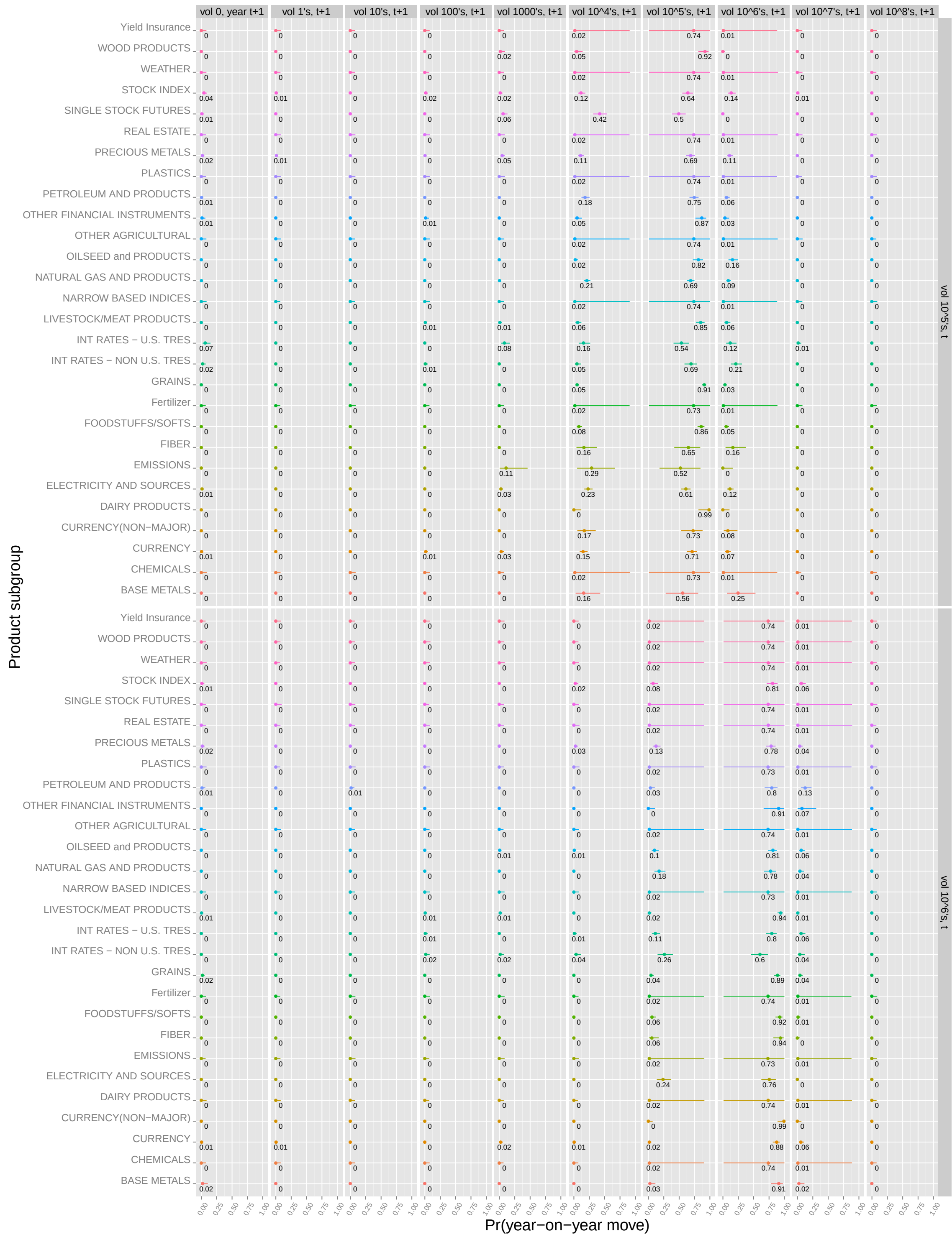


Figure 12: Transition matrix for Markov model of derivatives contract moving between states of annual trading volume by product type - part 4: transitions given annual volumes $\geq 10,000$ and $< 1,000,000$

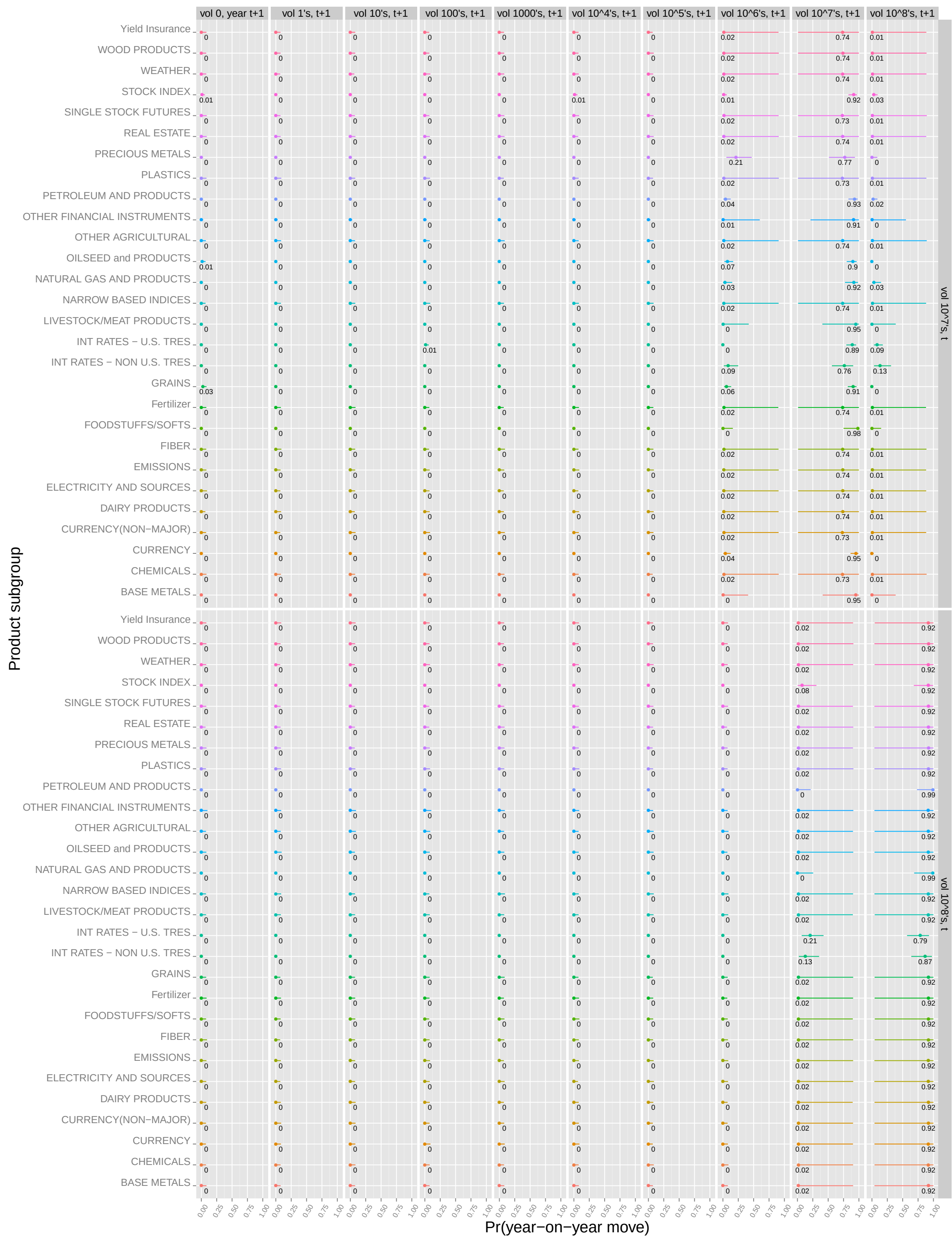


Figure 13: Transition matrix for Markov model of derivatives contract moving between states of annual trading volume by product type - part 5: transitions given annual volumes $\geq 1,000,000$

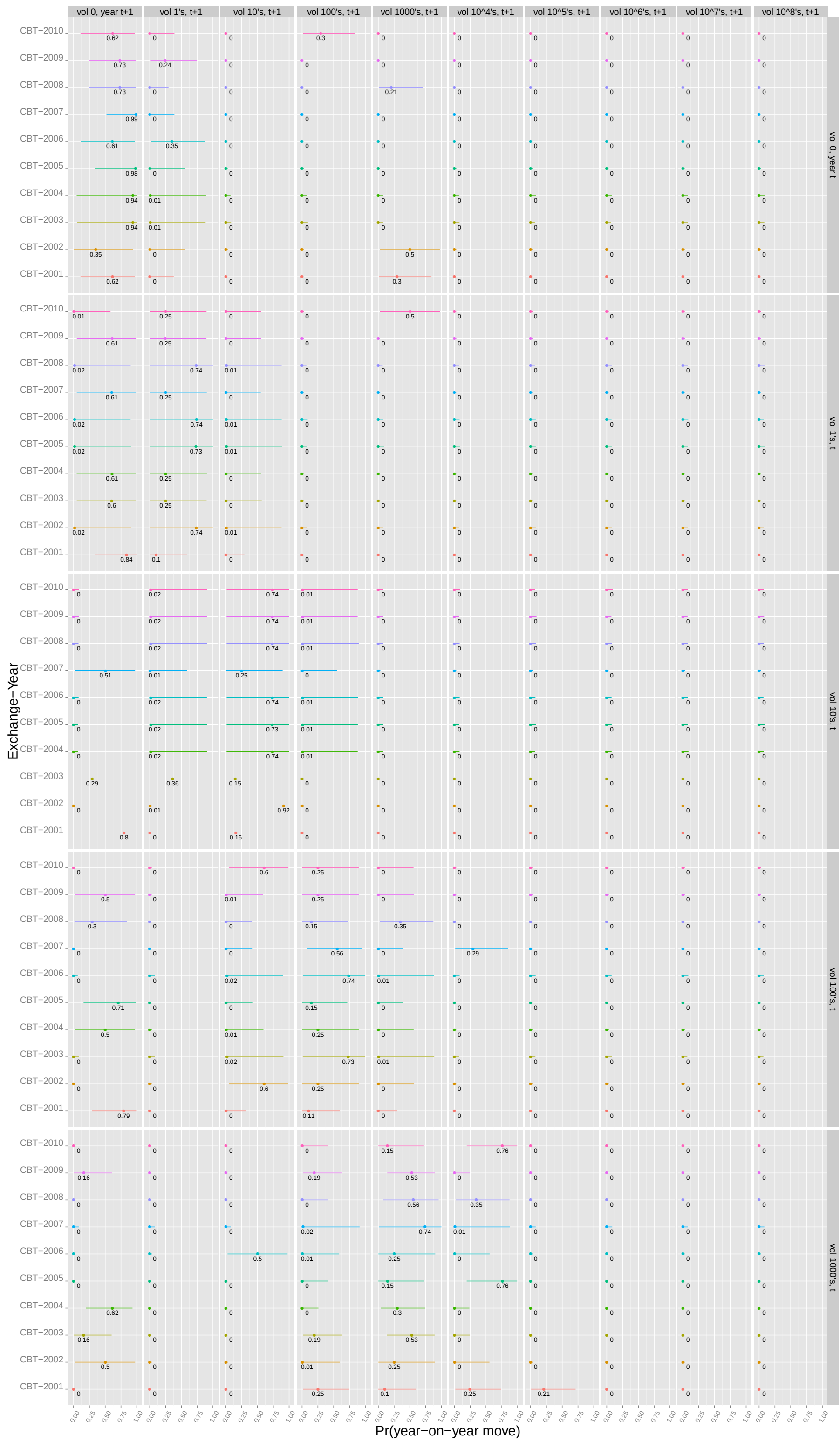


Figure 14: Transition matrix for Markov model of derivatives contract moving between states of annual trading volume by decade - CBT before and after CME merger (announced October 2006, finalized January 2008) - part 1: transitions given annual volumes $< 10,000$

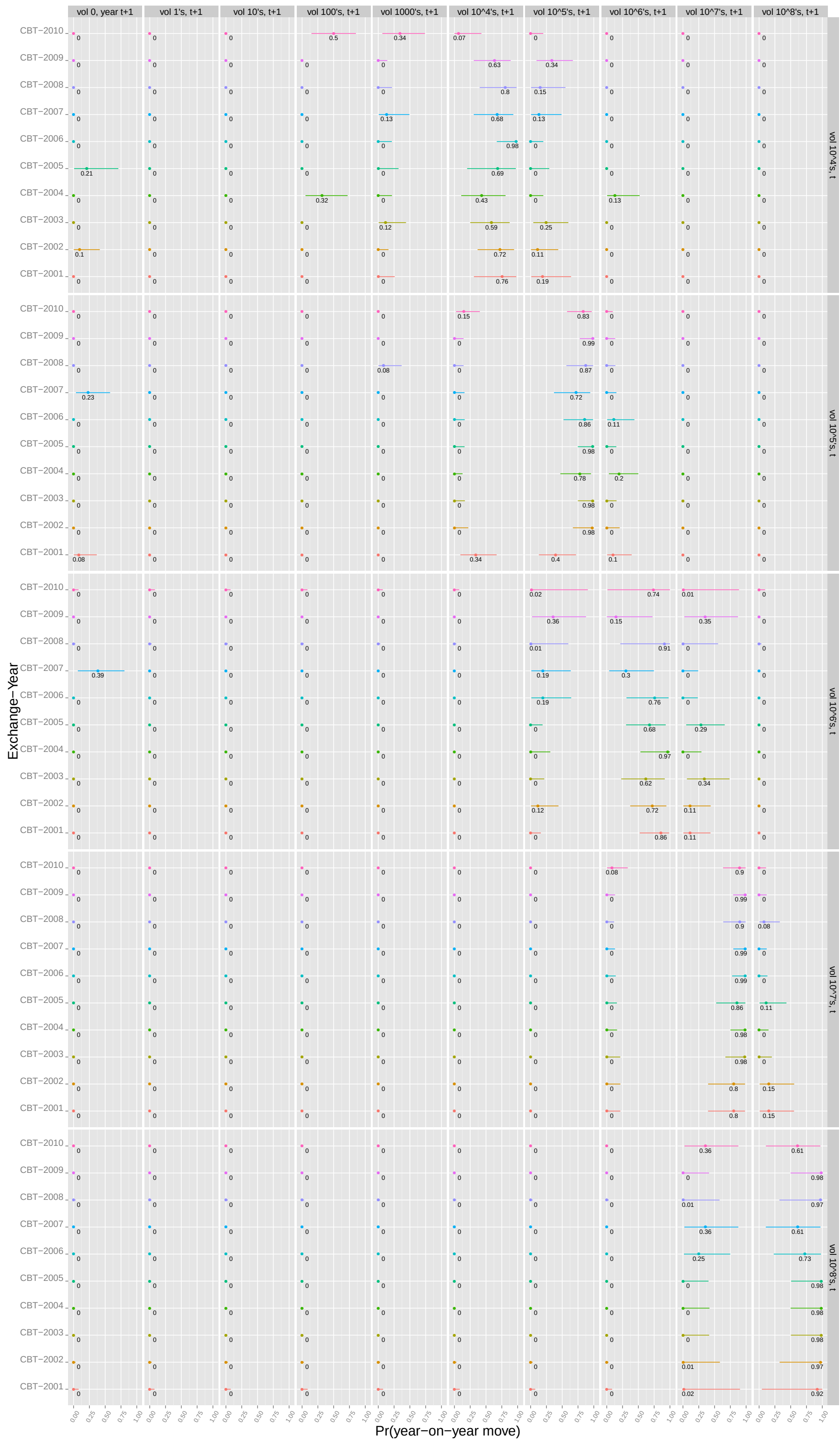


Figure 15: Transition matrix for Markov model of derivatives contract moving between states of annual trading volume by decade - CBT before and after CME merger (announced October 2006, finalized January 2008) - part 2: transitions given annual volumes $\geq 10,000$

Appendix C: Miscellaneous

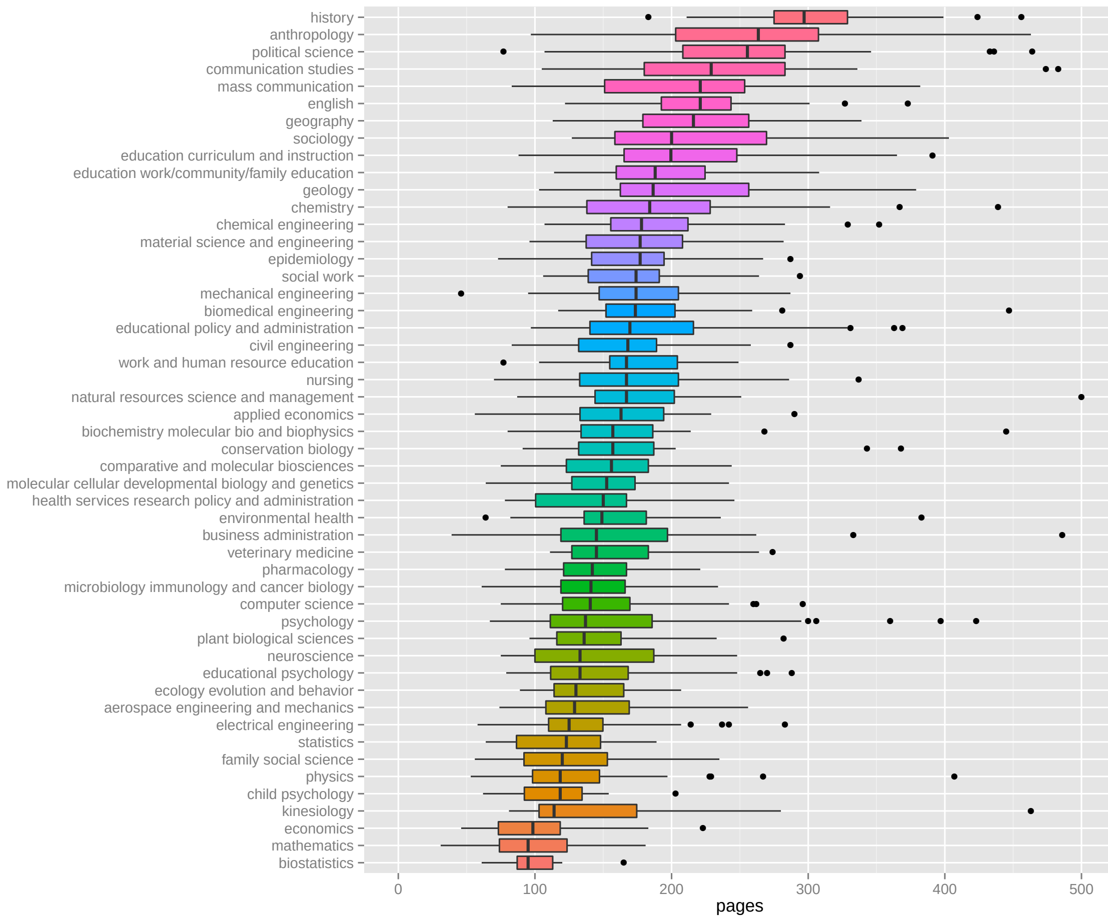


Figure 16: Average dissertation lengths from Beck (2013)

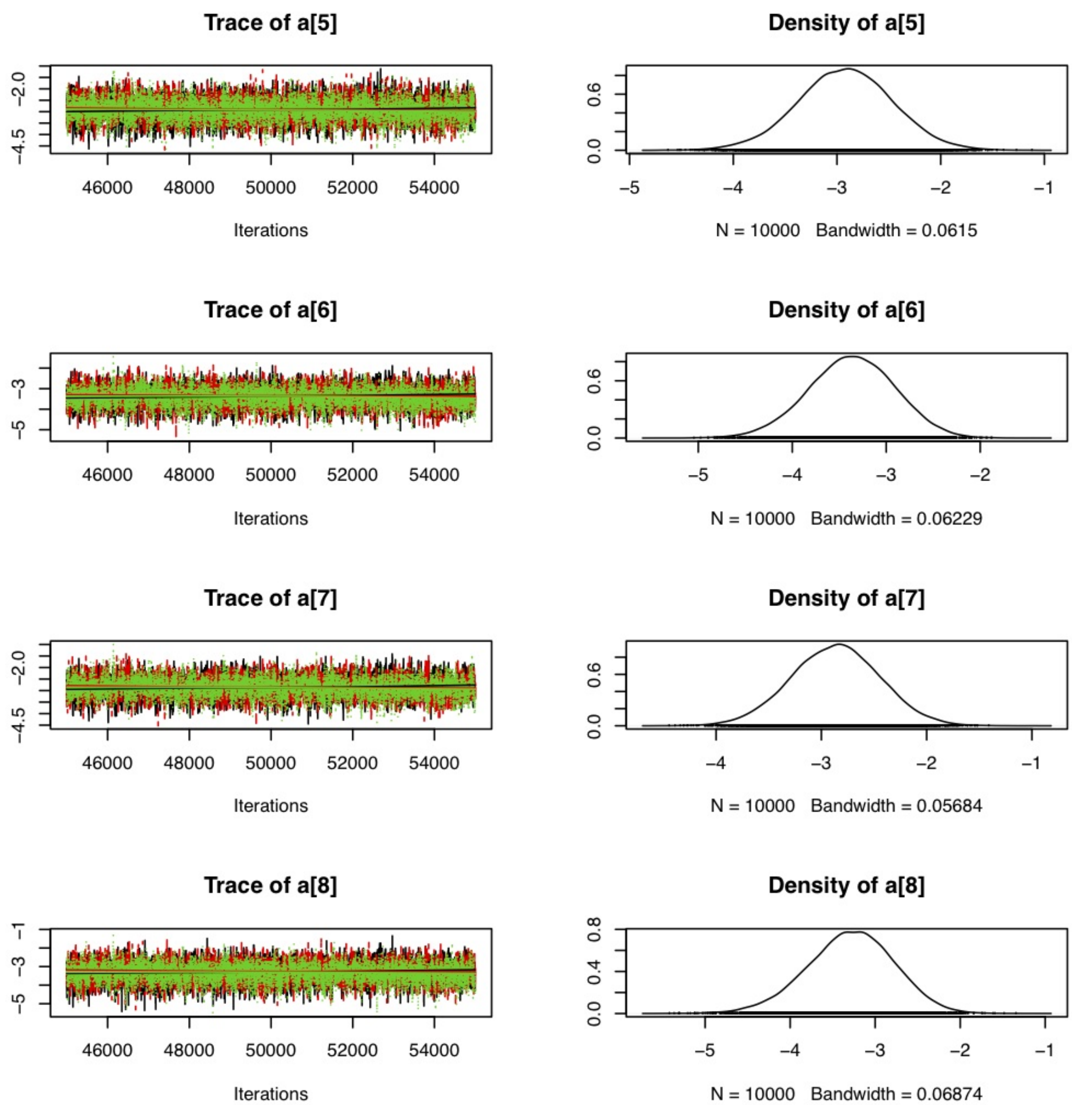


Figure 17: Diagnostics for Bayesian regression of economic damages given population affected, population killed, and GDP per capita the disaster's country-year - core training set. a[1] is the intercept for Flood, a[2] is the intercept for Storm , a[3] is the intercept for Earthquake, a[4] is the intercept for Drought

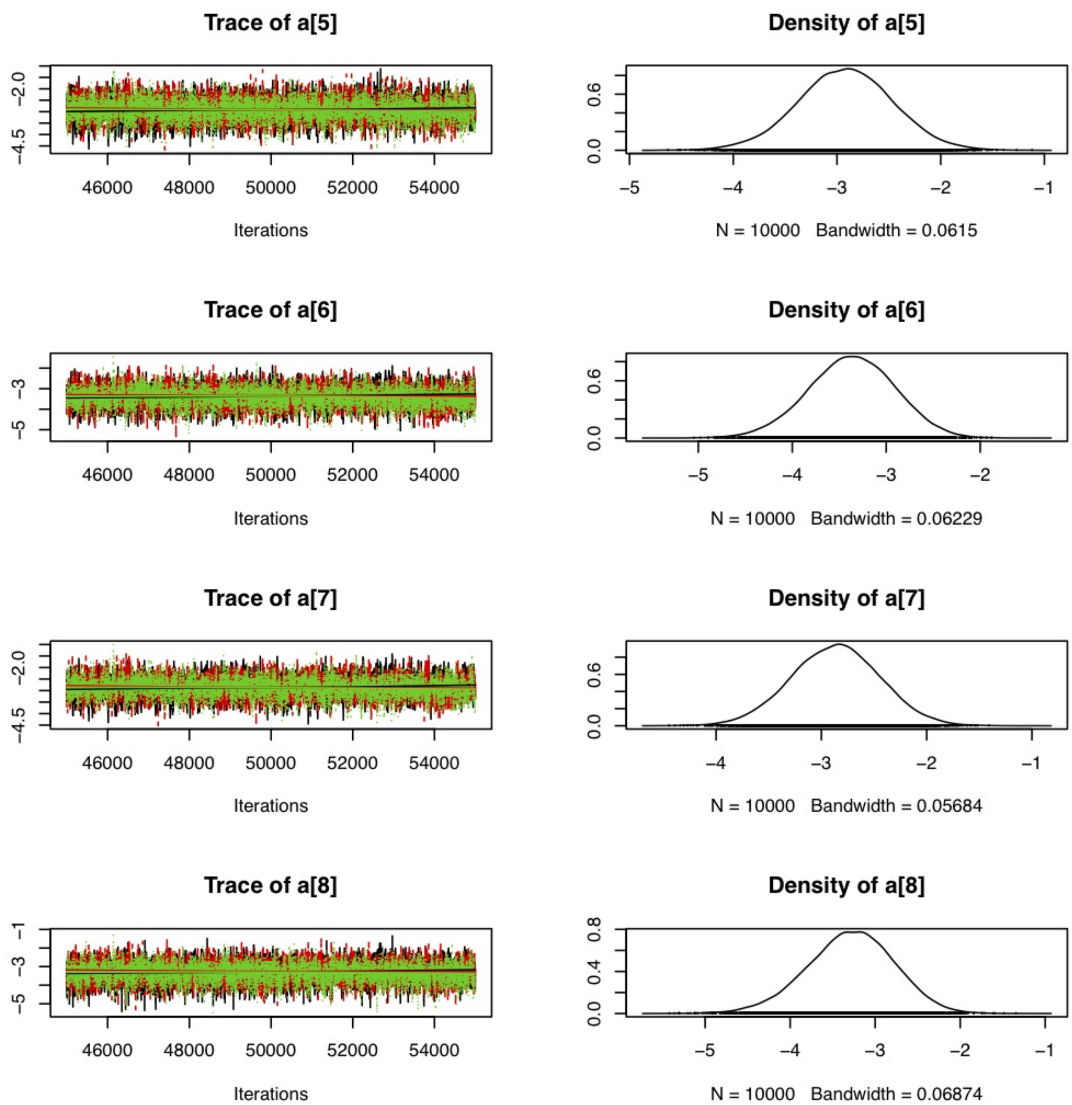


Figure 18: Diagnostics for Bayesian regression of economic damages given population affected, population killed, and GDP per capita the disaster's country-year - core training set. a[5] is the intercept for Extreme temperature, a[6] is the intercept for Mass movement wet , a[7] is the intercept for Wildfire, a[8] is the intercept for Volcano

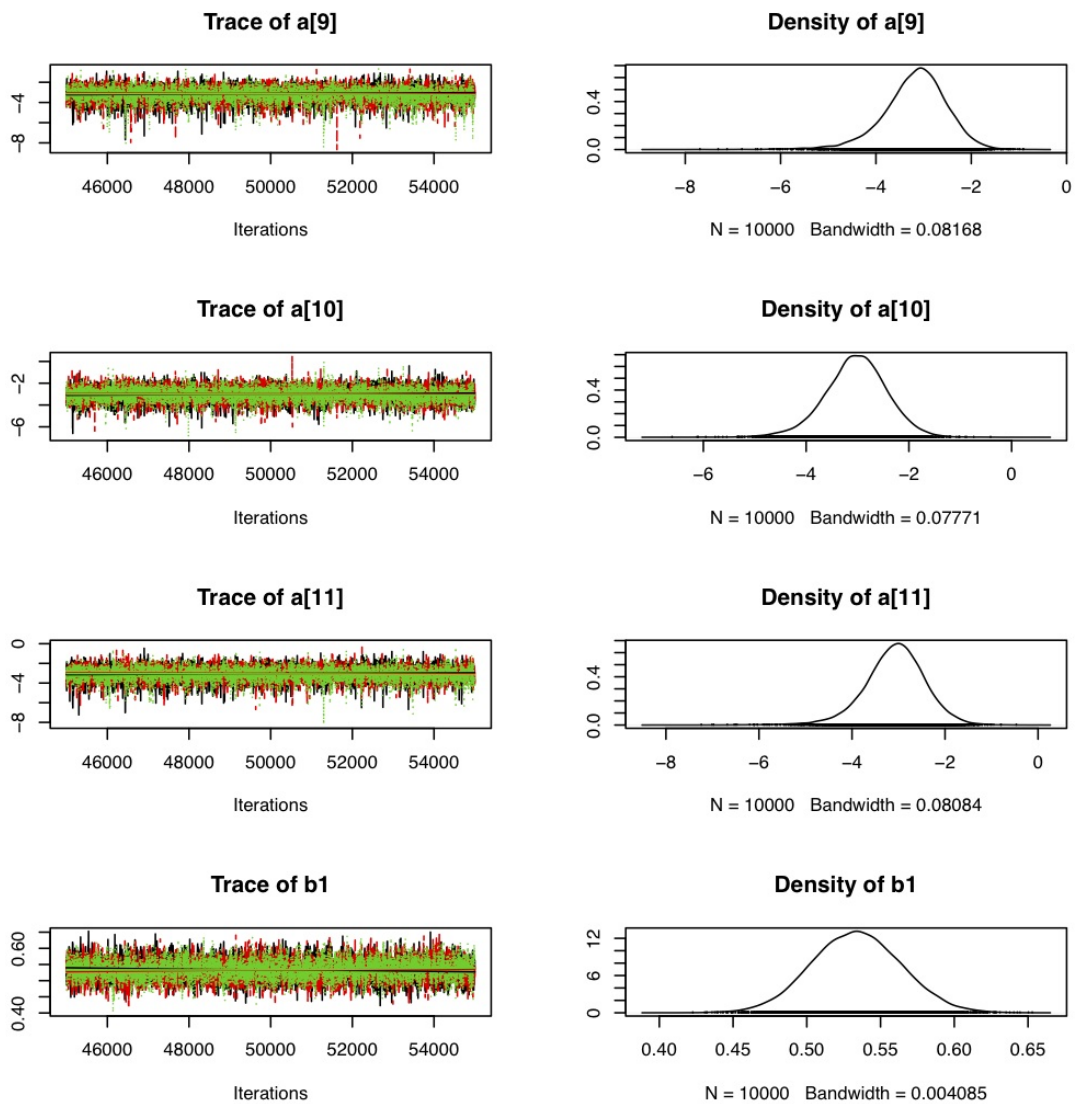


Figure 19: Diagnostics for Bayesian regression of economic damages given population affected, population killed, and GDP per capita the disaster's country-year - core training set. a[9] is the intercept for Epidemic, a[10] is the intercept for Insect infestation, a[11] is the intercept for Mass movement dry, b1 is the slope parameter for log GDP per capita

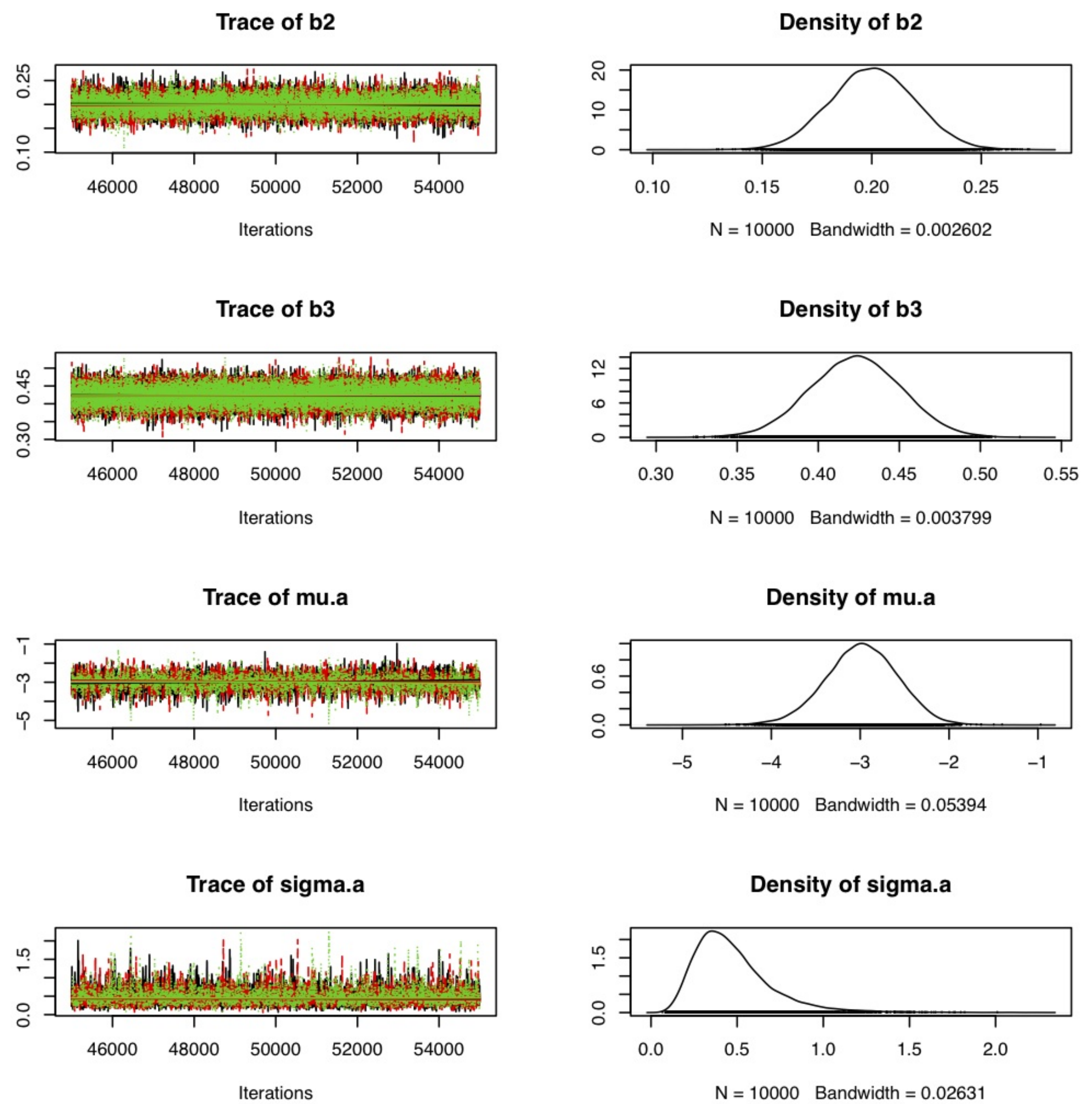


Figure 20: Diagnostics for Bayesian regression of economic damages given population affected, population killed, and GDP per capita the disaster's country-year - core training set, b2 is the slope parameter for log affected, b3 is the slope parameter for log killed, mu[a] represents the average intercept, sigma[a] represents the standard deviation of the average intercept

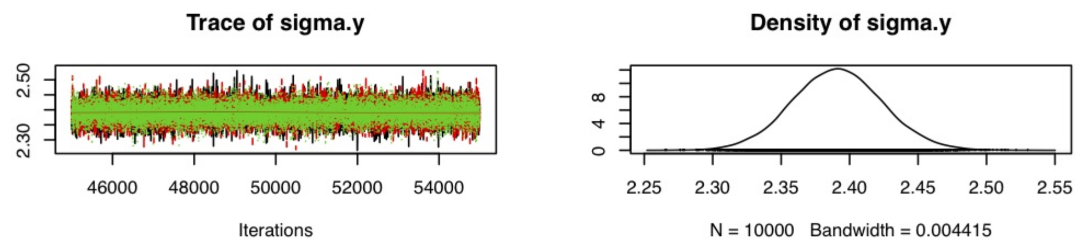


Figure 21: Diagnostics for Bayesian regression of economic damages given population affected, population killed, and GDP per capita the disaster's country-year - core training set. sigma[y] represents the standard deviation of observed economic damages around the predicted value

Table 2: Summary statistics of distributions of individual commodity futures returns. Annualized monthly 1959/7 - 2004/12. Note: EW index is an equally-weighted futures index.) The last two columns give the average pair-wise correlations of individual commodity futures with all other commodities and the correlation of a commodity future with the equally-weighted index.

Index	Obs	Arithmetic Mean Return	Geometric Mean Return	Stdev	Skewness	Kurtosis	Correlation w/ others	Correlation w/ index
EW Index	546	0.11	0.10	0.12	0.71	4.54	0.39	1.00
Copper	546	0.16	0.12	0.27	0.46	2.71	0.15	0.42
Cotton	546	0.08	0.05	0.23	0.79	4.03	0.05	0.24
Cocoa	546	0.09	0.04	0.32	0.81	1.70	0.04	0.29
Wheat	546	0.03	0.01	0.23	0.88	4.11	0.14	0.53
Corn	546	0.02	-0.00	0.22	1.73	11.03	0.16	0.58
Soybeans	546	0.09	0.06	0.26	1.86	13.32	0.17	0.65
Soybean Oil	546	0.14	0.09	0.31	1.61	7.22	0.12	0.55
Soybean Meal	546	0.14	0.09	0.32	2.67	21.18	0.16	0.59
Oats	546	0.03	-0.01	0.29	2.92	28.72	0.09	0.45
Sugar	527	0.11	0.02	0.45	1.23	3.47	0.05	0.37
Pork Bellies	519	0.10	0.03	0.36	0.52	1.65	0.10	0.40
Silver	498	0.08	0.03	0.32	1.87	17.98	0.14	0.47
Live Cattle	481	0.13	0.11	0.18	-0.24	1.93	0.10	0.35
Lean Hogs	466	0.15	0.12	0.27	0.13	1.55	0.13	0.44
Orange Juice	454	0.11	0.06	0.33	2.06	10.92	-0.02	0.12
Platinum	441	0.10	0.06	0.28	0.69	4.38	0.15	0.51
Lumber	422	0.06	0.02	0.30	0.46	1.48	0.04	0.20
Feeder Cattle	397	0.09	0.08	0.17	-0.55	3.01	0.07	0.26
Coffee	388	0.15	0.08	0.40	1.10	2.75	0.04	0.22
Gold	360	0.04	0.03	0.19	0.72	4.73	0.13	0.47
Palladium	335	0.13	0.07	0.36	0.45	2.65	0.13	0.49
Zinc	335	0.08	0.06	0.22	0.14	0.27	0.13	0.45
Lead	334	0.07	0.05	0.23	0.45	0.46	0.13	0.42
Heating Oil	313	0.19	0.14	0.33	1.24	5.54	0.11	0.38
Nickel	308	0.16	0.11	0.37	3.38	28.96	0.10	0.35
Crude Oil	261	0.21	0.15	0.34	0.64	3.21	0.11	0.45
Unleaded Gas	240	0.24	0.19	0.34	1.00	3.35	0.11	0.49
Rough Rice	220	-0.01	-0.06	0.30	1.25	5.17	0.03	0.17
Aluminum	210	0.06	0.04	0.24	1.55	8.19	0.10	0.41
Propane	208	0.30	0.21	0.49	4.07	36.00	0.08	0.42
Tin	185	0.02	0.01	0.18	0.54	2.69	0.11	0.37
Natural Gas	176	0.14	0.02	0.52	0.69	1.08	0.07	0.41
Milk	107	0.06	0.04	0.19	-0.11	0.96	-0.01	-0.01
Butter	99	0.25	0.17	0.40	0.50	1.34	0.01	0.12
Coal	41	-0.02	-0.04	0.22	-0.52	0.76	0.16	0.55
Electricity	20	-0.47	-0.55	0.40	0.44	-0.83	0.09	0.44

Table 3: Realized percentage forward premia on weather futures (CDD) 1999 to 2004

City	Mean	t.stat	SD	Max	Min	nobs
at	9.37	1.75	42.41	214.29	-121.09	63
ba						0
bo	17.29	2.38	30.01	114.95	-25.12	17
ch	12.74	2.07	39.97	135.96	-100.45	42
ck	24.43	5.42	34.31	107.66	-97.27	58
da	3.97	1.29	23.80	45.66	-106.55	60
dm	6.77	1.24	36.33	91.28	-68.30	44
de						0
ho	-0.32	-0.04	23.01	39.80	-39.35	8
kc	16.99	1.27	46.39	82.65	-40.48	12
lv	0.23	0.07	17.35	72.86	-30.40	31
mn	23.51	1.47	62.14	124.00	-89.67	15
ny	-9.64	-2.15	35.53	106.41	-167.57	63
ph	2.00	0.54	27.24	110.71	-74.06	54
po	-11.16	-0.91	53.21	128.40	-142.50	19
sa	-9.78	-0.41	47.99	38.75	-67.17	4
sl						0
tu	-1.28	-0.39	19.88	33.99	-90.53	36
Top 5 Cities	5.76	2.11	36.79	214.29	-167.57	182

Table 4: Realized percentage forward premia on weather futures (CDD) 2005 to 2008

City	Mean	t.stat	SD	Max	Min	nobs
at	-7.77	-2.84	28.54	59.92	-125.09	109
ba	10.22	1.38	25.70	56.72	-21.40	12
bo	-6.02	-1.38	37.97	81.95	-207.36	76
ch	-8.34	-1.84	59.92	88.26	-262.31	175
ck	-8.80	-2.77	35.67	100.68	-112.52	126
da	0.52	0.31	17.45	71.43	-39.14	111
dm	3.61	1.75	21.33	60.00	-50.38	107
de						0
ho	-1.32	-0.84	11.25	22.82	-28.79	52
kc	0.56	0.20	26.18	50.81	-111.21	87
lv	1.31	1.12	9.76	29.37	-16.74	69
mn	10.65	4.65	22.30	89.56	-42.83	95
ny	-16.89	-4.90	46.67	134.78	-219.73	183
ph	-6.70	-1.53	35.34	95.95	-110.87	65
po	3.37	0.23	91.16	77.65	-493.18	38
sa	5.42	1.64	32.93	69.41	-139.29	100
sl	6.15			6.15	6.15	1
tu	6.67	4.40	10.72	27.32	-15.14	50
Top 5 Cities	-8.10	-3.36	40.68	134.78	-192.47	284
Top5:2000						0
Top5:2001						0
Top5:2002	-3.08	-0.46	37.92	46.62	-167.57	32
Top5:2003	15.30	3.01	43.09	214.29	-121.09	72
Top5:2004	0.58	0.19	27.33	57.15	-106.55	78
Top5:2005	-0.52	-0.17	29.34	71.43	-83.85	93
Top5:2006	-8.61	-1.58	52.03	134.78	-192.47	91
Top5:2007	-16.33	-4.29	37.11	49.86	-170.28	95
Top5:2008	16.43	2.07	17.74	31.07	-14.15	5

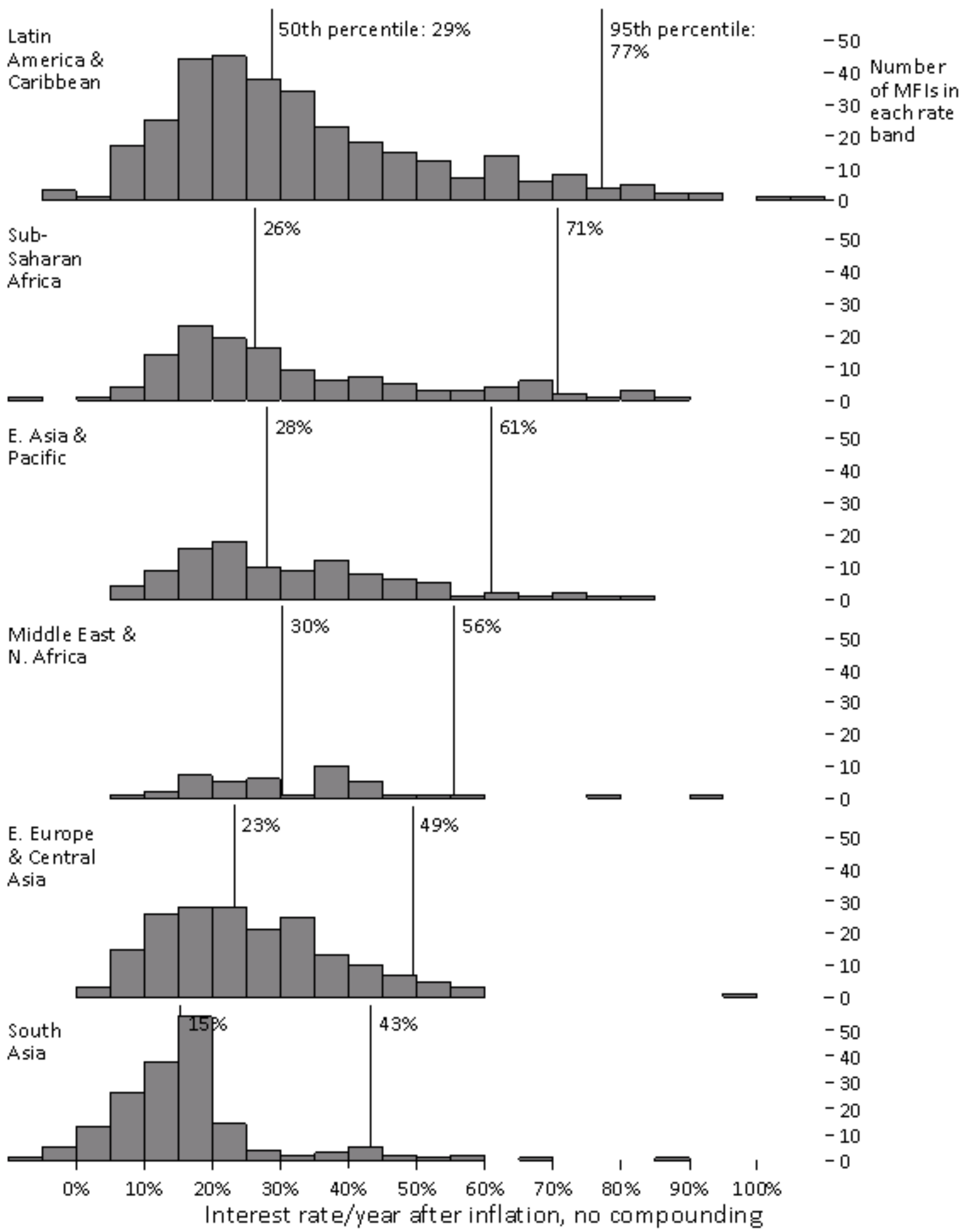
Table 5: Realized percentage forward premia on weather futures (HDD) 1999 to 2004

City	Mean	t.stat	SD	Max	Min	nobs
at	-0.96	-0.39	26.25	96.69	-71.43	113
ba						0
bo	1.16	0.49	14.87	26.49	-25.56	40
ch	2.40	2.04	12.04	56.53	-32.01	105
ck	3.85	1.84	19.11	55.63	-54.27	83
da	1.51	0.32	38.60	81.19	-155.00	67
dm	-2.23	-0.92	18.19	23.08	-58.97	56
de						0
ho	-3.75	-0.19	48.36	72.16	-60.00	6
kc	7.79	2.03	12.72	24.70	-19.48	11
lv	0.16	0.04	19.36	68.73	-20.71	23
mn	1.36	0.52	14.74	18.01	-58.65	32
ny	-0.30	-0.21	13.76	30.04	-28.47	98
ph	-5.99	-2.77	15.73	22.19	-74.68	53
po	-0.24	-0.03	32.15	33.83	-125.37	21
sa	17.65	1.18	25.92	47.35	-0.42	3
sl						0
tu	-0.48	-0.09	27.04	57.08	-32.89	27
Top 5 Cities	0.47	0.34	22.11	96.69	-155.00	266

Table 6: Realized percentage forward premia on weather futures (HDD) 2005 to 2008

City	Mean	t.stat	SD	Max	Min	nobs
at	-2.33	-1.27	23.28	75.00	-93.78	162
ba	3.46	2.42	10.08	30.00	-14.24	50
bo	2.11	1.41	15.69	86.51	-25.30	109
ch	1.93	2.25	13.98	43.06	-47.83	266
ck	0.23	0.20	17.04	37.49	-80.57	221
da	14.67	3.05	55.47	442.86	-61.95	133
dm	3.83	3.06	15.87	57.54	-38.60	161
de	11.95	1.12	15.12	22.64	1.25	2
ho	12.36	1.43	64.74	420.71	-80.05	56
kc	2.23	1.53	19.01	86.11	-64.52	170
lv	3.81	0.66	44.79	193.75	-81.25	61
mn	3.70	3.60	13.86	90.82	-33.22	182
ny	7.60	8.27	16.12	87.44	-30.95	308
ph	0.09	0.06	14.68	67.33	-31.69	89
po	-1.73	-0.93	13.38	42.94	-26.21	52
sa	5.16	1.55	18.87	65.92	-25.00	32
sl	-5.25	-0.73	16.01	11.64	-27.09	5
tu	20.70	1.58	80.95	322.92	-86.80	38
Top 5 Cities	4.51	4.54	19.94	220.91	-46.18	403
Top5:2000	-23.25	-2.70	27.24	21.53	-66.61	10
Top5:2001						0
Top5:2002	-3.96	-0.78	33.26	47.17	-155.00	43
Top5:2003	0.62	0.30	20.16	64.27	-71.43	94
Top5:2004	2.87	1.78	16.24	96.69	-32.01	102
Top5:2005	0.35	0.26	14.07	58.62	-44.19	113
Top5:2006	5.95	4.24	15.06	33.37	-46.18	115
Top5:2007	10.65	3.69	29.87	220.91	-17.72	107
Top5:2008	-0.65	-0.46	11.75	41.77	-26.75	68

Figure 22: Counts of MFIs by region and interest rate, adjusted for inflation but not compounding, 2009 (graphic from Roodman (2011) using data from MIX - Microfinance Information eX-change (2011))



Appendix D: January Pricing

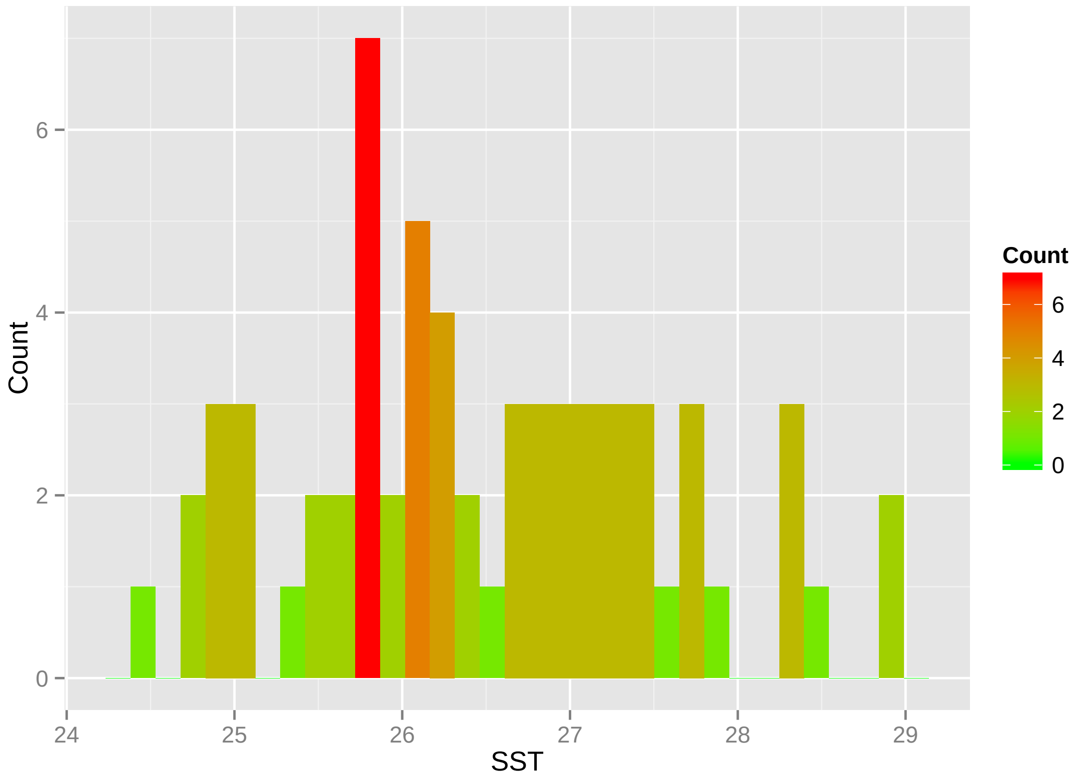


Figure 23: Histogram of January SST for Niño 3.4 ERSST.3b

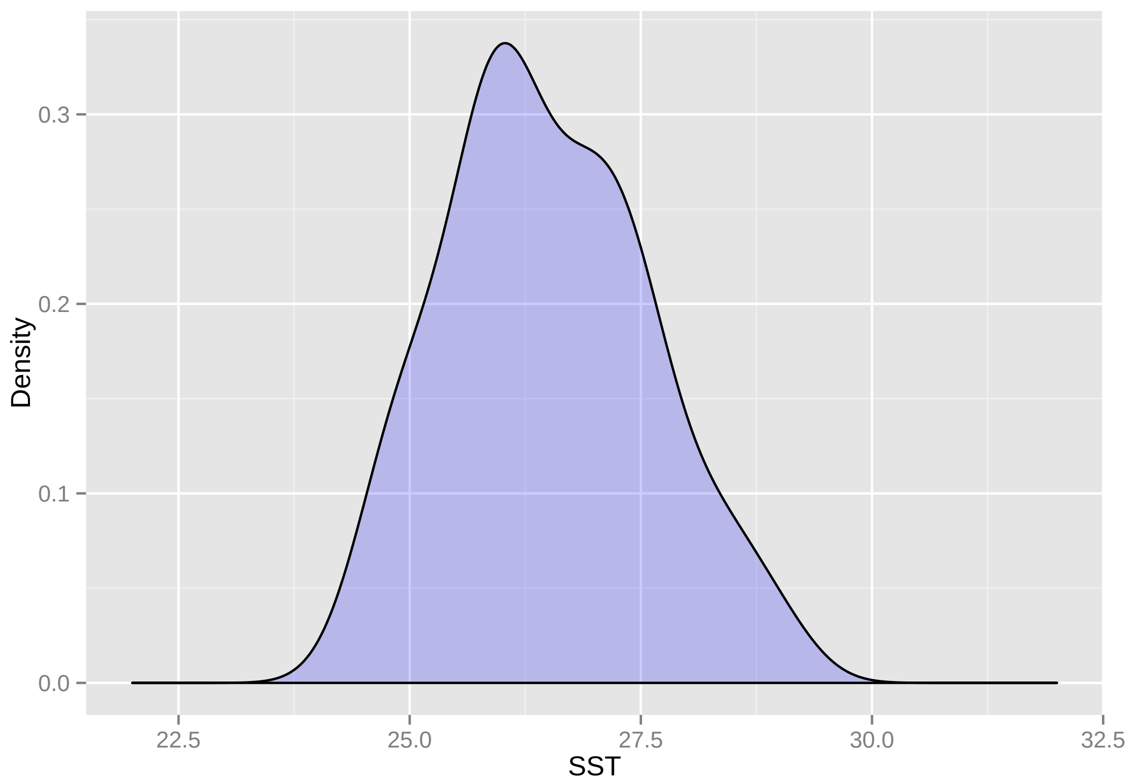


Figure 24: Kernel density estimate of January SST for Niño 3.4 ERSST.3b

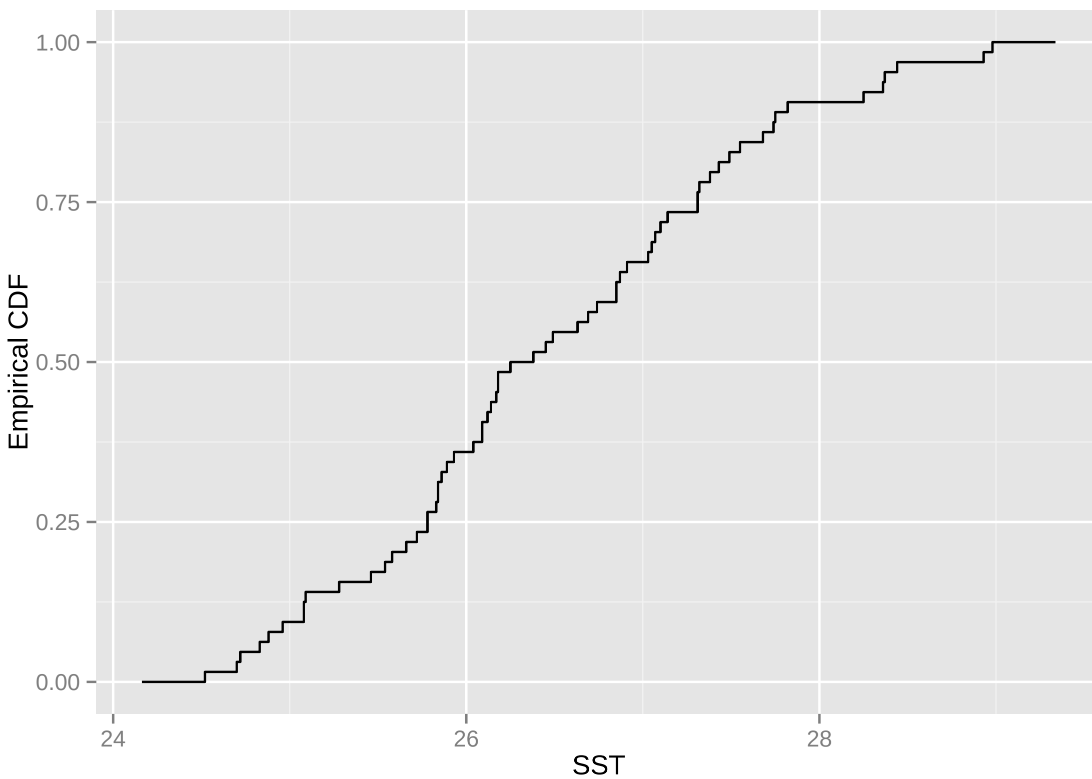


Figure 25: ECDF of January SST for Niño 3.4 ERSST.3b

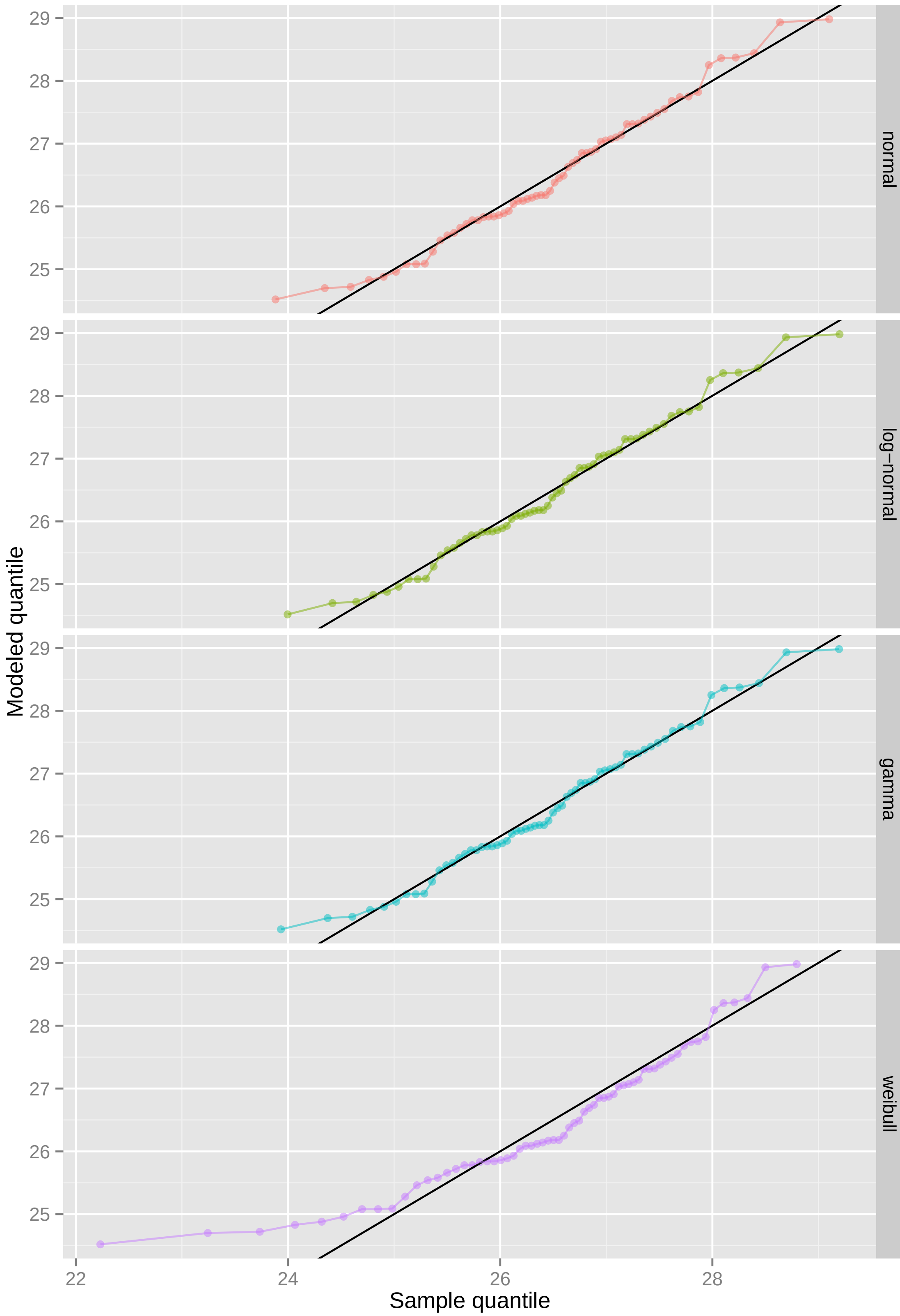


Figure 26: QQ plots of January SST for Niño 3.4 ERSST.3b compared to samples from various distributions (n=2 million)

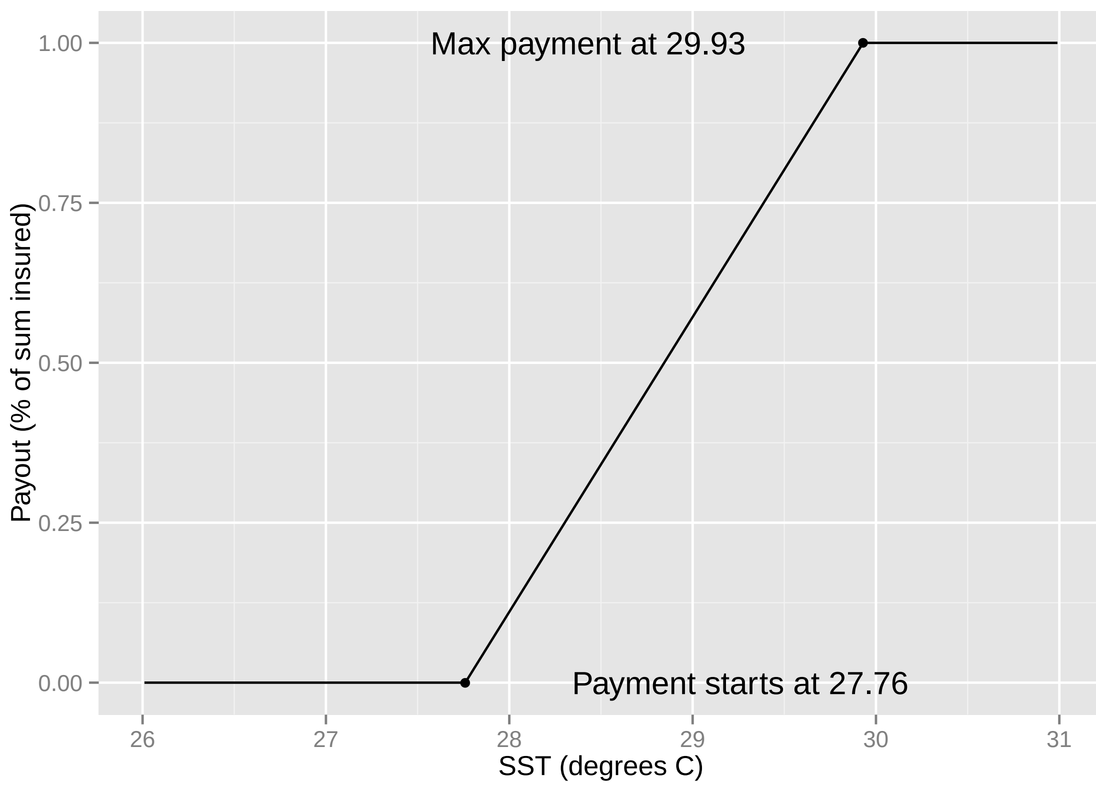


Figure 27: Payout function for call option on January SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations above the baseline

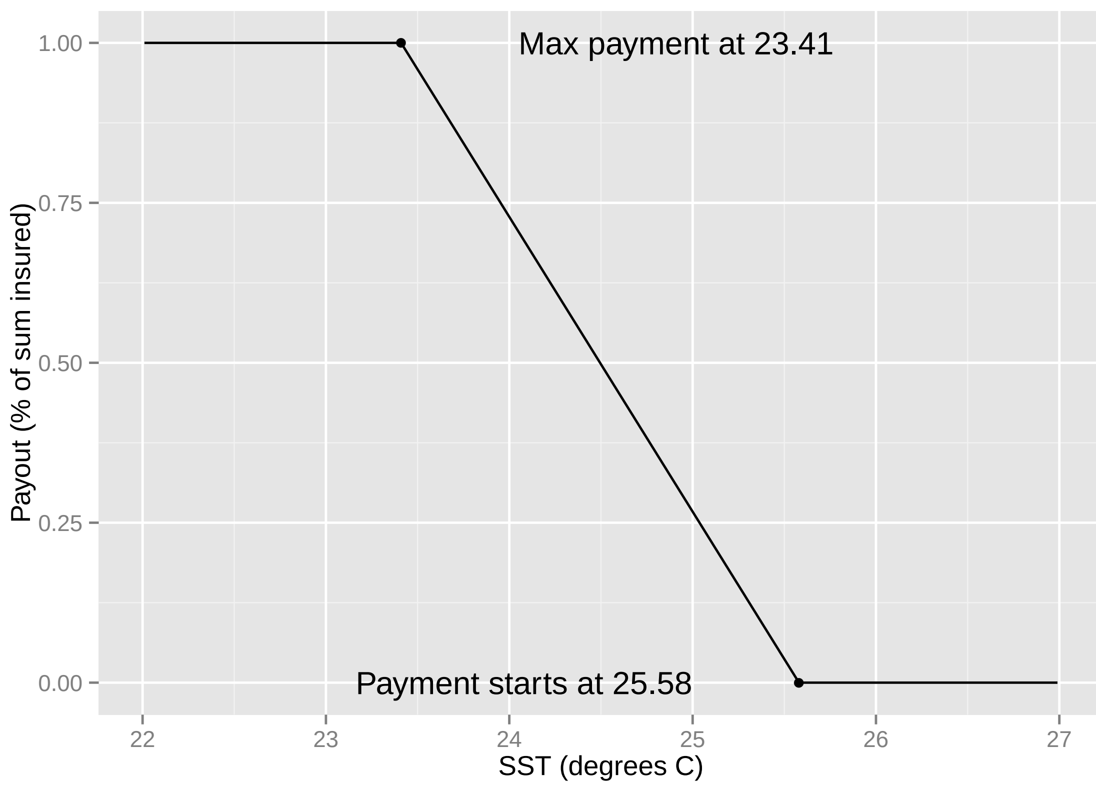


Figure 28: Payout function for put option on January SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

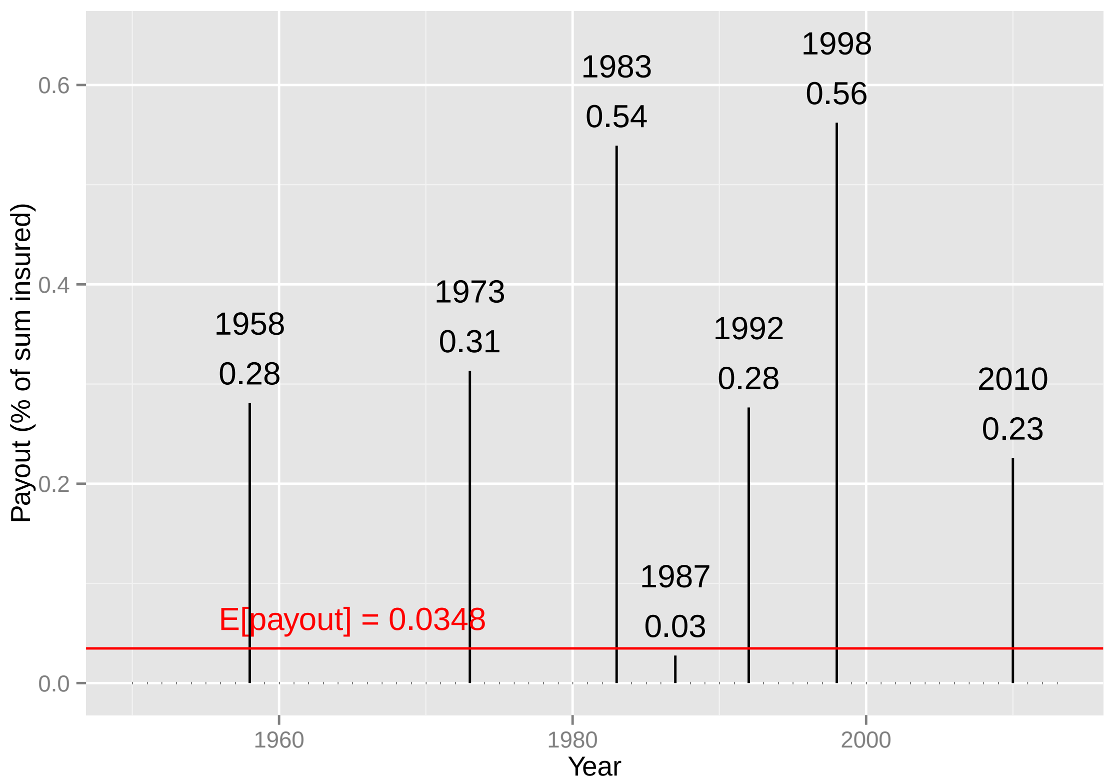


Figure 29: Historical burn on call option for January SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations above the baseline

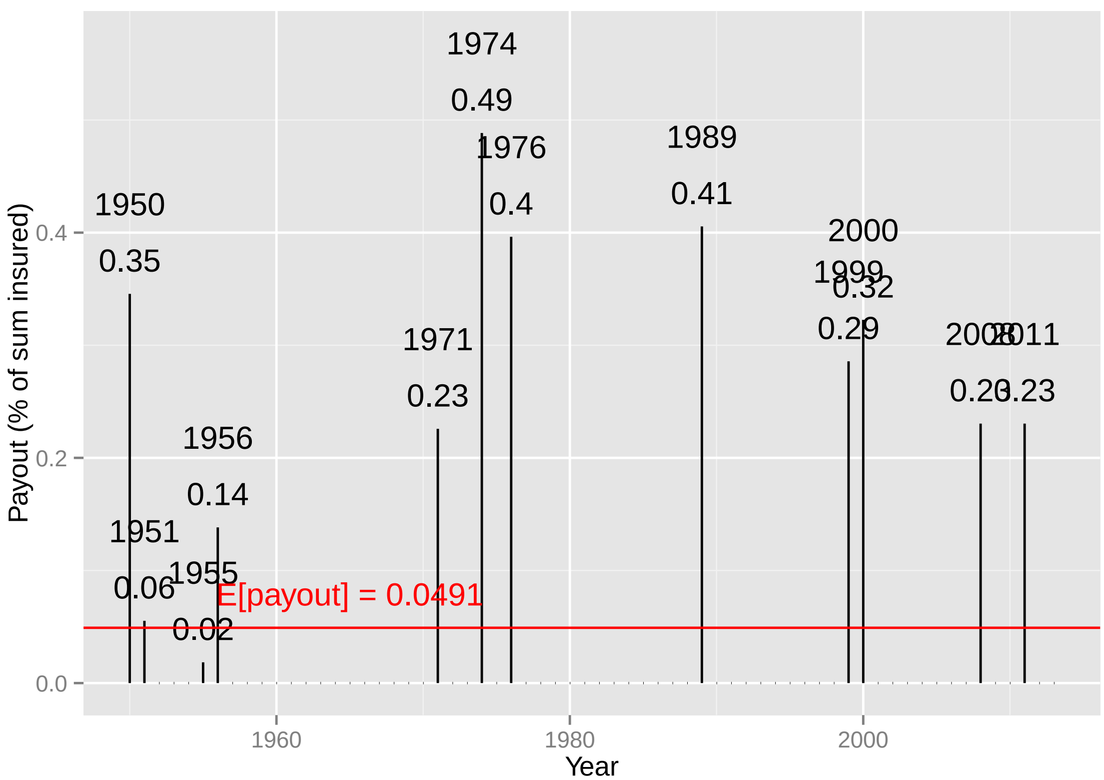


Figure 30: Historical burn on put option on January SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

Table 7: Bayesian regression linking January Niño 3.4 SST anomalies to average of relevant IRI ensemble forecasts

	mean	sd	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q	n_eff	Rhat
November forecast average covering January Niño 3.4 SST anomalies									
α	-0.20	0.10	-0.50	-0.30	-0.20	-0.10	0.10	95812	1
β	1.10	0.10	0.80	1.00	1.10	1.10	1.40	93027	1
σ_y^2	0.20	0.10	0.10	0.10	0.20	0.20	0.60	50725	1
October forecast average covering January Niño 3.4 SST anomalies									
α	-0.30	0.20	-0.60	-0.40	-0.30	-0.20	0.10	94118	1
β	1.10	0.20	0.80	1.00	1.10	1.30	1.50	92674	1
σ_y^2	0.30	0.20	0.10	0.20	0.20	0.30	0.80	51375	1
September forecast average covering January Niño 3.4 SST anomalies									
α	-0.40	0.20	-0.80	-0.50	-0.40	-0.30	0.00	95595	1
β	1.30	0.30	0.70	1.10	1.30	1.40	1.80	91858	1
σ_y^2	0.40	0.30	0.10	0.20	0.30	0.50	1.10	54547	1
August forecast average covering January Niño 3.4 SST anomalies									
α	-0.50	0.20	-0.90	-0.60	-0.50	-0.30	0.00	91793	1
β	1.40	0.30	0.80	1.20	1.40	1.60	2.00	86819	1
σ_y^2	0.50	0.30	0.20	0.30	0.40	0.60	1.30	53668	1
July forecast average covering January Niño 3.4 SST anomalies									
α	-0.50	0.30	-1.00	-0.60	-0.50	-0.30	0.10	92662	1
β	1.60	0.50	0.70	1.30	1.60	1.90	2.50	88029	1
σ_y^2	0.60	0.50	0.20	0.40	0.50	0.80	1.90	50557	1
June forecast average covering January Niño 3.4 SST anomalies									
α	-0.40	0.30	-0.90	-0.50	-0.40	-0.20	0.20	95558	1
β	1.70	0.50	0.70	1.40	1.70	2.10	2.80	92277	1
σ_y^2	0.70	0.50	0.20	0.40	0.60	0.90	1.90	58029	1
May forecast average covering January Niño 3.4 SST anomalies									
α	-0.40	0.30	-1.00	-0.60	-0.40	-0.20	0.20	97312	1
β	2.00	0.80	0.40	1.50	2.00	2.50	3.60	91197	1
σ_y^2	1.00	0.70	0.30	0.60	0.80	1.20	2.70	55990	1
April forecast average covering January Niño 3.4 SST anomalies									
α	-0.50	0.40	-1.20	-0.70	-0.50	-0.20	0.30	85663	1
β	1.90	1.00	-0.10	1.30	1.90	2.50	3.90	82329	1
σ_y^2	1.20	0.80	0.40	0.70	1.00	1.40	3.20	56639	1
March forecast average covering January Niño 3.4 SST anomalies									
α	-0.30	0.40	-1.10	-0.60	-0.30	-0.10	0.40	100933	1
β	1.60	1.60	-1.60	0.70	1.60	2.60	4.90	90351	1
σ_y^2	1.70	1.30	0.50	0.90	1.30	2.00	4.80	56487	1

Table 8: Call option prices for January Nino 3.4 SST conditioned on IRI ensemble forecasts released in November

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	24.33	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	24.43	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.54	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.65	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.75	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.86	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	24.96	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	25.07	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	25.18	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.28	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.39	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.49	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.60	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.70	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.81	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	25.91	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.02	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.13	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.23	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	26.34	0.00	0.00	0.00	0.00	0.00
0.00	0.00	26.44	0.00	0.00	0.00	0.00	0.00
0.10	0.00	26.54	0.00	0.00	0.00	0.00	0.00
0.20	0.00	26.65	0.00	0.00	0.00	0.00	0.00
0.30	0.00	26.76	0.00	0.00	0.00	0.00	0.00
0.40	0.00	26.86	0.00	0.00	0.00	0.00	0.03
0.50	0.01	26.97	0.00	0.00	0.00	0.00	0.08
0.60	0.01	27.07	0.00	0.00	0.00	0.00	0.13
0.70	0.01	27.17	0.00	0.00	0.00	0.00	0.18
0.80	0.02	27.28	0.00	0.00	0.00	0.00	0.23
0.90	0.03	27.39	0.00	0.00	0.00	0.00	0.29
1.00	0.04	27.50	0.00	0.00	0.00	0.02	0.35
1.10	0.06	27.60	0.00	0.00	0.00	0.07	0.40
1.20	0.08	27.70	0.00	0.00	0.00	0.12	0.44
1.30	0.10	27.81	0.00	0.00	0.02	0.17	0.50
1.40	0.13	27.92	0.00	0.00	0.07	0.22	0.56
1.50	0.17	28.02	0.00	0.00	0.12	0.27	0.61
1.60	0.20	28.13	0.00	0.02	0.17	0.32	0.67
1.70	0.24	28.23	0.00	0.06	0.22	0.37	0.72
1.80	0.29	28.34	0.00	0.11	0.27	0.42	0.77
1.90	0.33	28.44	0.00	0.16	0.31	0.47	0.83
2.00	0.37	28.55	0.00	0.21	0.36	0.52	0.88

Table 9: Call option prices for January Nino 3.4 SST conditioned on IRI ensemble forecasts released in October

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	24.10	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	24.22	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.33	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.45	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.56	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.68	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	24.79	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	24.90	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	25.02	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.14	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.25	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.36	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.47	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.59	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.70	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	25.82	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	25.93	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.04	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.15	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	26.27	0.00	0.00	0.00	0.00	0.00
0.00	0.00	26.39	0.00	0.00	0.00	0.00	0.00
0.10	0.00	26.51	0.00	0.00	0.00	0.00	0.00
0.20	0.00	26.62	0.00	0.00	0.00	0.00	0.00
0.30	0.00	26.73	0.00	0.00	0.00	0.00	0.04
0.40	0.01	26.84	0.00	0.00	0.00	0.00	0.10
0.50	0.01	26.96	0.00	0.00	0.00	0.00	0.15
0.60	0.01	27.07	0.00	0.00	0.00	0.00	0.21
0.70	0.02	27.19	0.00	0.00	0.00	0.00	0.26
0.80	0.03	27.30	0.00	0.00	0.00	0.00	0.32
0.90	0.04	27.41	0.00	0.00	0.00	0.01	0.38
1.00	0.06	27.53	0.00	0.00	0.00	0.06	0.43
1.10	0.08	27.64	0.00	0.00	0.00	0.11	0.49
1.20	0.11	27.76	0.00	0.00	0.00	0.17	0.55
1.30	0.13	27.87	0.00	0.00	0.05	0.22	0.61
1.40	0.17	27.99	0.00	0.00	0.10	0.28	0.67
1.50	0.21	28.10	0.00	0.00	0.16	0.33	0.73
1.60	0.25	28.21	0.00	0.03	0.21	0.39	0.79
1.70	0.29	28.33	0.00	0.08	0.26	0.44	0.86
1.80	0.33	28.44	0.00	0.13	0.31	0.50	0.92
1.90	0.38	28.55	0.00	0.18	0.36	0.55	0.98
2.00	0.43	28.67	0.00	0.23	0.42	0.61	1.00

Table 10: Call option prices for January Nino 3.4 SST conditioned on IRI ensemble forecasts released in September

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	23.77	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	23.89	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.02	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.14	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.27	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.40	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	24.52	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	24.64	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	24.77	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	24.90	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.02	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.15	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.27	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.40	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.52	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	25.65	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	25.77	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	25.91	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.03	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	26.15	0.00	0.00	0.00	0.00	0.00
0.00	0.00	26.28	0.00	0.00	0.00	0.00	0.00
0.10	0.00	26.40	0.00	0.00	0.00	0.00	0.00
0.20	0.01	26.52	0.00	0.00	0.00	0.00	0.05
0.30	0.01	26.65	0.00	0.00	0.00	0.00	0.12
0.40	0.01	26.77	0.00	0.00	0.00	0.00	0.17
0.50	0.02	26.90	0.00	0.00	0.00	0.00	0.24
0.60	0.02	27.03	0.00	0.00	0.00	0.00	0.30
0.70	0.03	27.15	0.00	0.00	0.00	0.00	0.37
0.80	0.04	27.28	0.00	0.00	0.00	0.00	0.42
0.90	0.06	27.40	0.00	0.00	0.00	0.03	0.49
1.00	0.08	27.53	0.00	0.00	0.00	0.09	0.55
1.10	0.10	27.65	0.00	0.00	0.00	0.15	0.62
1.20	0.13	27.78	0.00	0.00	0.01	0.21	0.68
1.30	0.16	27.90	0.00	0.00	0.06	0.27	0.74
1.40	0.20	28.03	0.00	0.00	0.12	0.34	0.82
1.50	0.24	28.15	0.00	0.00	0.18	0.40	0.88
1.60	0.29	28.28	0.00	0.02	0.24	0.46	0.96
1.70	0.33	28.41	0.00	0.08	0.30	0.52	1.00
1.80	0.38	28.54	0.00	0.13	0.36	0.59	1.00
1.90	0.43	28.66	0.00	0.18	0.41	0.64	1.00
2.00	0.48	28.79	0.00	0.24	0.47	0.71	1.00

Table 11: Call option prices for January Nino 3.4 SST conditioned on IRI ensemble forecasts released in August

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	23.42	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	23.56	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	23.70	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	23.84	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	23.98	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.12	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	24.25	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	24.40	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	24.53	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	24.67	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	24.81	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	24.95	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.08	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.22	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.37	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	25.50	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	25.65	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	25.78	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	25.92	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	26.06	0.00	0.00	0.00	0.00	0.00
0.00	0.00	26.19	0.00	0.00	0.00	0.00	0.00
0.10	0.00	26.33	0.00	0.00	0.00	0.00	0.01
0.20	0.01	26.48	0.00	0.00	0.00	0.00	0.07
0.30	0.01	26.61	0.00	0.00	0.00	0.00	0.13
0.40	0.01	26.75	0.00	0.00	0.00	0.00	0.20
0.50	0.02	26.89	0.00	0.00	0.00	0.00	0.27
0.60	0.03	27.03	0.00	0.00	0.00	0.00	0.33
0.70	0.04	27.17	0.00	0.00	0.00	0.00	0.41
0.80	0.05	27.31	0.00	0.00	0.00	0.00	0.48
0.90	0.07	27.45	0.00	0.00	0.00	0.07	0.55
1.00	0.10	27.58	0.00	0.00	0.00	0.13	0.63
1.10	0.13	27.73	0.00	0.00	0.00	0.20	0.70
1.20	0.16	27.86	0.00	0.00	0.05	0.27	0.77
1.30	0.20	28.00	0.00	0.00	0.11	0.34	0.85
1.40	0.25	28.15	0.00	0.00	0.18	0.40	0.93
1.50	0.29	28.28	0.00	0.01	0.24	0.47	1.00
1.60	0.34	28.42	0.00	0.06	0.30	0.54	1.00
1.70	0.39	28.56	0.00	0.13	0.37	0.61	1.00
1.80	0.45	28.70	0.00	0.18	0.43	0.68	1.00
1.90	0.50	28.83	0.00	0.24	0.49	0.75	1.00
2.00	0.55	28.97	0.00	0.30	0.56	0.82	1.00

Table 12: Call option prices for January Nino 3.4 SST conditioned on IRI ensemble forecasts released in July

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	23.02	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	23.18	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	23.34	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	23.51	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	23.66	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	23.82	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	23.98	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	24.13	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	24.30	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	24.45	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	24.61	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	24.77	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	24.93	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.09	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.24	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	25.40	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	25.56	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	25.73	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	25.88	0.00	0.00	0.00	0.00	0.00
-0.10	0.01	26.05	0.00	0.00	0.00	0.00	0.01
0.00	0.01	26.20	0.00	0.00	0.00	0.00	0.07
0.10	0.01	26.37	0.00	0.00	0.00	0.00	0.14
0.20	0.01	26.53	0.00	0.00	0.00	0.00	0.22
0.30	0.02	26.67	0.00	0.00	0.00	0.00	0.29
0.40	0.03	26.84	0.00	0.00	0.00	0.00	0.38
0.50	0.04	27.00	0.00	0.00	0.00	0.00	0.45
0.60	0.05	27.16	0.00	0.00	0.00	0.00	0.53
0.70	0.08	27.32	0.00	0.00	0.00	0.04	0.62
0.80	0.10	27.47	0.00	0.00	0.00	0.12	0.69
0.90	0.13	27.64	0.00	0.00	0.00	0.20	0.80
1.00	0.17	27.79	0.00	0.00	0.02	0.27	0.87
1.10	0.21	27.95	0.00	0.00	0.09	0.35	0.98
1.20	0.26	28.11	0.00	0.00	0.16	0.43	1.00
1.30	0.31	28.27	0.00	0.00	0.23	0.51	1.00
1.40	0.36	28.43	0.00	0.02	0.31	0.59	1.00
1.50	0.41	28.59	0.00	0.09	0.38	0.68	1.00
1.60	0.47	28.75	0.00	0.15	0.46	0.76	1.00
1.70	0.52	28.90	0.00	0.22	0.53	0.83	1.00
1.80	0.57	29.07	0.00	0.28	0.60	0.92	1.00
1.90	0.62	29.23	0.00	0.35	0.68	1.00	1.00
2.00	0.67	29.40	0.00	0.42	0.75	1.00	1.00

Table 13: Call option prices for January Nino 3.4 SST conditioned on IRI ensemble forecasts released in June

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	22.83	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	23.02	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	23.18	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	23.35	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	23.53	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	23.70	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	23.88	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	24.05	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	24.21	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	24.39	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	24.56	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	24.73	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	24.91	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.08	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.26	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	25.43	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	25.60	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	25.78	0.00	0.00	0.00	0.00	0.00
-0.20	0.01	25.95	0.00	0.00	0.00	0.00	0.00
-0.10	0.01	26.12	0.00	0.00	0.00	0.00	0.07
0.00	0.01	26.29	0.00	0.00	0.00	0.00	0.14
0.10	0.01	26.46	0.00	0.00	0.00	0.00	0.21
0.20	0.02	26.63	0.00	0.00	0.00	0.00	0.31
0.30	0.03	26.81	0.00	0.00	0.00	0.00	0.38
0.40	0.04	26.98	0.00	0.00	0.00	0.00	0.47
0.50	0.06	27.15	0.00	0.00	0.00	0.00	0.56
0.60	0.08	27.33	0.00	0.00	0.00	0.06	0.65
0.70	0.11	27.50	0.00	0.00	0.00	0.15	0.75
0.80	0.15	27.67	0.00	0.00	0.00	0.23	0.84
0.90	0.19	27.85	0.00	0.00	0.04	0.32	0.94
1.00	0.23	28.02	0.00	0.00	0.11	0.40	1.00
1.10	0.29	28.19	0.00	0.00	0.20	0.49	1.00
1.20	0.34	28.36	0.00	0.00	0.28	0.58	1.00
1.30	0.40	28.54	0.00	0.05	0.36	0.67	1.00
1.40	0.46	28.71	0.00	0.12	0.44	0.75	1.00
1.50	0.51	28.88	0.00	0.19	0.52	0.84	1.00
1.60	0.57	29.06	0.00	0.26	0.60	0.93	1.00
1.70	0.61	29.22	0.00	0.33	0.67	1.00	1.00
1.80	0.66	29.40	0.00	0.40	0.76	1.00	1.00
1.90	0.70	29.57	0.00	0.46	0.83	1.00	1.00
2.00	0.74	29.74	0.00	0.53	0.91	1.00	1.00

Table 14: Call option prices for January Nino 3.4 SST conditioned on IRI ensemble forecasts released in May

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	22.33	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	22.53	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	22.73	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	22.92	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	23.12	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	23.32	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	23.51	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	23.71	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	23.91	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	24.11	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	24.30	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	24.50	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	24.71	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	24.90	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.10	0.00	0.00	0.00	0.00	0.00
-0.50	0.01	25.30	0.00	0.00	0.00	0.00	0.00
-0.40	0.01	25.50	0.00	0.00	0.00	0.00	0.00
-0.30	0.01	25.70	0.00	0.00	0.00	0.00	0.05
-0.20	0.01	25.89	0.00	0.00	0.00	0.00	0.11
-0.10	0.01	26.09	0.00	0.00	0.00	0.00	0.19
0.00	0.02	26.29	0.00	0.00	0.00	0.00	0.27
0.10	0.03	26.49	0.00	0.00	0.00	0.00	0.37
0.20	0.04	26.69	0.00	0.00	0.00	0.00	0.46
0.30	0.05	26.88	0.00	0.00	0.00	0.00	0.56
0.40	0.07	27.08	0.00	0.00	0.00	0.00	0.67
0.50	0.10	27.29	0.00	0.00	0.00	0.09	0.77
0.60	0.13	27.48	0.00	0.00	0.00	0.19	0.88
0.70	0.18	27.68	0.00	0.00	0.00	0.28	1.00
0.80	0.22	27.88	0.00	0.00	0.06	0.39	1.00
0.90	0.28	28.08	0.00	0.00	0.15	0.49	1.00
1.00	0.33	28.28	0.00	0.00	0.24	0.59	1.00
1.10	0.39	28.46	0.00	0.00	0.32	0.69	1.00
1.20	0.45	28.66	0.00	0.03	0.42	0.80	1.00
1.30	0.51	28.87	0.00	0.11	0.51	0.91	1.00
1.40	0.56	29.07	0.00	0.18	0.60	1.00	1.00
1.50	0.61	29.26	0.00	0.26	0.69	1.00	1.00
1.60	0.65	29.47	0.00	0.33	0.79	1.00	1.00
1.70	0.69	29.66	0.00	0.41	0.87	1.00	1.00
1.80	0.73	29.87	0.00	0.49	0.97	1.00	1.00
1.90	0.75	30.05	0.00	0.55	1.00	1.00	1.00
2.00	0.78	30.26	0.00	0.62	1.00	1.00	1.00

Table 15: Call option prices for January Nino 3.4 SST conditioned on IRI ensemble forecasts released in April

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.01	22.41	0.00	0.00	0.00	0.00	0.00
-1.90	0.01	22.60	0.00	0.00	0.00	0.00	0.00
-1.80	0.01	22.79	0.00	0.00	0.00	0.00	0.00
-1.70	0.01	22.98	0.00	0.00	0.00	0.00	0.00
-1.60	0.01	23.18	0.00	0.00	0.00	0.00	0.00
-1.50	0.01	23.37	0.00	0.00	0.00	0.00	0.00
-1.40	0.01	23.56	0.00	0.00	0.00	0.00	0.00
-1.30	0.01	23.74	0.00	0.00	0.00	0.00	0.00
-1.20	0.01	23.93	0.00	0.00	0.00	0.00	0.00
-1.10	0.01	24.12	0.00	0.00	0.00	0.00	0.00
-1.00	0.01	24.32	0.00	0.00	0.00	0.00	0.00
-0.90	0.01	24.50	0.00	0.00	0.00	0.00	0.00
-0.80	0.01	24.69	0.00	0.00	0.00	0.00	0.00
-0.70	0.01	24.88	0.00	0.00	0.00	0.00	0.00
-0.60	0.01	25.07	0.00	0.00	0.00	0.00	0.01
-0.50	0.01	25.25	0.00	0.00	0.00	0.00	0.06
-0.40	0.01	25.45	0.00	0.00	0.00	0.00	0.12
-0.30	0.01	25.63	0.00	0.00	0.00	0.00	0.15
-0.20	0.01	25.83	0.00	0.00	0.00	0.00	0.22
-0.10	0.02	26.02	0.00	0.00	0.00	0.00	0.27
0.00	0.02	26.21	0.00	0.00	0.00	0.00	0.35
0.10	0.03	26.39	0.00	0.00	0.00	0.00	0.43
0.20	0.04	26.58	0.00	0.00	0.00	0.00	0.51
0.30	0.05	26.78	0.00	0.00	0.00	0.00	0.60
0.40	0.07	26.97	0.00	0.00	0.00	0.00	0.71
0.50	0.10	27.16	0.00	0.00	0.00	0.06	0.82
0.60	0.13	27.35	0.00	0.00	0.00	0.16	0.94
0.70	0.17	27.54	0.00	0.00	0.00	0.26	1.00
0.80	0.21	27.73	0.00	0.00	0.00	0.35	1.00
0.90	0.26	27.92	0.00	0.00	0.07	0.45	1.00
1.00	0.30	28.10	0.00	0.00	0.16	0.55	1.00
1.10	0.36	28.30	0.00	0.00	0.25	0.67	1.00
1.20	0.41	28.48	0.00	0.00	0.34	0.77	1.00
1.30	0.46	28.68	0.00	0.00	0.42	0.88	1.00
1.40	0.50	28.86	0.00	0.03	0.51	0.98	1.00
1.50	0.55	29.06	0.00	0.10	0.60	1.00	1.00
1.60	0.59	29.25	0.00	0.17	0.68	1.00	1.00
1.70	0.62	29.43	0.00	0.23	0.77	1.00	1.00
1.80	0.66	29.63	0.00	0.30	0.87	1.00	1.00
1.90	0.69	29.82	0.00	0.37	0.95	1.00	1.00
2.00	0.71	30.01	0.00	0.43	1.00	1.00	1.00

Table 16: Call option prices for January Nino 3.4 SST conditioned on IRI ensemble forecasts released in March

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.05	23.08	0.00	0.00	0.00	0.00	1.00
-1.90	0.05	23.24	0.00	0.00	0.00	0.00	1.00
-1.80	0.05	23.40	0.00	0.00	0.00	0.00	0.96
-1.70	0.04	23.57	0.00	0.00	0.00	0.00	0.91
-1.60	0.04	23.73	0.00	0.00	0.00	0.00	0.82
-1.50	0.04	23.89	0.00	0.00	0.00	0.00	0.79
-1.40	0.04	24.06	0.00	0.00	0.00	0.00	0.75
-1.30	0.04	24.21	0.00	0.00	0.00	0.00	0.69
-1.20	0.03	24.39	0.00	0.00	0.00	0.00	0.63
-1.10	0.03	24.55	0.00	0.00	0.00	0.00	0.59
-1.00	0.03	24.72	0.00	0.00	0.00	0.00	0.56
-0.90	0.03	24.87	0.00	0.00	0.00	0.00	0.53
-0.80	0.03	25.05	0.00	0.00	0.00	0.00	0.51
-0.70	0.03	25.20	0.00	0.00	0.00	0.00	0.45
-0.60	0.03	25.37	0.00	0.00	0.00	0.00	0.43
-0.50	0.03	25.54	0.00	0.00	0.00	0.00	0.44
-0.40	0.03	25.69	0.00	0.00	0.00	0.00	0.44
-0.30	0.03	25.86	0.00	0.00	0.00	0.00	0.44
-0.20	0.03	26.01	0.00	0.00	0.00	0.00	0.46
-0.10	0.04	26.19	0.00	0.00	0.00	0.00	0.53
0.00	0.04	26.33	0.00	0.00	0.00	0.00	0.58
0.10	0.05	26.50	0.00	0.00	0.00	0.00	0.65
0.20	0.07	26.67	0.00	0.00	0.00	0.00	0.76
0.30	0.09	26.84	0.00	0.00	0.00	0.00	0.90
0.40	0.11	26.99	0.00	0.00	0.00	0.06	1.00
0.50	0.14	27.17	0.00	0.00	0.00	0.16	1.00
0.60	0.18	27.32	0.00	0.00	0.00	0.25	1.00
0.70	0.21	27.49	0.00	0.00	0.00	0.36	1.00
0.80	0.25	27.66	0.00	0.00	0.00	0.46	1.00
0.90	0.29	27.82	0.00	0.00	0.02	0.57	1.00
1.00	0.33	27.98	0.00	0.00	0.10	0.67	1.00
1.10	0.37	28.14	0.00	0.00	0.18	0.78	1.00
1.20	0.40	28.30	0.00	0.00	0.25	0.89	1.00
1.30	0.43	28.47	0.00	0.00	0.33	1.00	1.00
1.40	0.46	28.63	0.00	0.00	0.40	1.00	1.00
1.50	0.49	28.80	0.00	0.00	0.48	1.00	1.00
1.60	0.52	28.96	0.00	0.00	0.55	1.00	1.00
1.70	0.54	29.13	0.00	0.00	0.63	1.00	1.00
1.80	0.56	29.29	0.00	0.00	0.71	1.00	1.00
1.90	0.58	29.45	0.00	0.00	0.78	1.00	1.00
2.00	0.60	29.62	0.00	0.00	0.86	1.00	1.00

Table 17: Put option prices for January Nino 3.4 SST conditioned on IRI ensemble forecasts released in November

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.57	24.33	0.05	0.42	0.58	0.74	1.00
-1.90	0.53	24.43	0.01	0.37	0.53	0.69	1.00
-1.80	0.48	24.54	0.00	0.32	0.48	0.63	0.99
-1.70	0.43	24.65	0.00	0.28	0.43	0.58	0.93
-1.60	0.39	24.75	0.00	0.23	0.38	0.53	0.88
-1.50	0.34	24.86	0.00	0.18	0.33	0.48	0.82
-1.40	0.30	24.96	0.00	0.14	0.28	0.43	0.77
-1.30	0.26	25.07	0.00	0.09	0.24	0.38	0.72
-1.20	0.21	25.18	0.00	0.04	0.19	0.33	0.66
-1.10	0.18	25.28	0.00	0.00	0.14	0.28	0.61
-1.00	0.14	25.39	0.00	0.00	0.09	0.23	0.56
-0.90	0.11	25.49	0.00	0.00	0.04	0.18	0.51
-0.80	0.08	25.60	0.00	0.00	0.00	0.13	0.45
-0.70	0.06	25.70	0.00	0.00	0.00	0.08	0.40
-0.60	0.04	25.81	0.00	0.00	0.00	0.03	0.34
-0.50	0.03	25.91	0.00	0.00	0.00	0.00	0.29
-0.40	0.02	26.02	0.00	0.00	0.00	0.00	0.25
-0.30	0.01	26.13	0.00	0.00	0.00	0.00	0.20
-0.20	0.01	26.23	0.00	0.00	0.00	0.00	0.15
-0.10	0.01	26.34	0.00	0.00	0.00	0.00	0.09
0.00	0.00	26.44	0.00	0.00	0.00	0.00	0.04
0.10	0.00	26.54	0.00	0.00	0.00	0.00	0.00
0.20	0.00	26.65	0.00	0.00	0.00	0.00	0.00
0.30	0.00	26.76	0.00	0.00	0.00	0.00	0.00
0.40	0.00	26.86	0.00	0.00	0.00	0.00	0.00
0.50	0.00	26.97	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.07	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.17	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.28	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.39	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.50	0.00	0.00	0.00	0.00	0.00
1.10	0.00	27.60	0.00	0.00	0.00	0.00	0.00
1.20	0.00	27.70	0.00	0.00	0.00	0.00	0.00
1.30	0.00	27.81	0.00	0.00	0.00	0.00	0.00
1.40	0.00	27.92	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.02	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.13	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.23	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.34	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.44	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.55	0.00	0.00	0.00	0.00	0.00

Table 18: Put option prices for January Nino 3.4 SST conditioned on IRI ensemble forecasts released in October

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.66	24.10	0.05	0.49	0.68	0.88	1.00
-1.90	0.61	24.22	0.01	0.43	0.63	0.82	1.00
-1.80	0.57	24.33	0.00	0.38	0.57	0.76	1.00
-1.70	0.52	24.45	0.00	0.34	0.52	0.71	1.00
-1.60	0.47	24.56	0.00	0.29	0.47	0.65	1.00
-1.50	0.42	24.68	0.00	0.24	0.42	0.59	1.00
-1.40	0.38	24.79	0.00	0.19	0.36	0.54	0.95
-1.30	0.33	24.90	0.00	0.14	0.31	0.49	0.88
-1.20	0.28	25.02	0.00	0.08	0.26	0.43	0.82
-1.10	0.24	25.14	0.00	0.03	0.21	0.38	0.76
-1.00	0.20	25.25	0.00	0.00	0.15	0.32	0.70
-0.90	0.16	25.36	0.00	0.00	0.10	0.27	0.65
-0.80	0.13	25.47	0.00	0.00	0.05	0.22	0.59
-0.70	0.10	25.59	0.00	0.00	0.00	0.16	0.54
-0.60	0.08	25.70	0.00	0.00	0.00	0.11	0.46
-0.50	0.06	25.82	0.00	0.00	0.00	0.05	0.41
-0.40	0.04	25.93	0.00	0.00	0.00	0.00	0.36
-0.30	0.03	26.04	0.00	0.00	0.00	0.00	0.31
-0.20	0.02	26.15	0.00	0.00	0.00	0.00	0.26
-0.10	0.01	26.27	0.00	0.00	0.00	0.00	0.20
0.00	0.01	26.39	0.00	0.00	0.00	0.00	0.14
0.10	0.01	26.51	0.00	0.00	0.00	0.00	0.09
0.20	0.00	26.62	0.00	0.00	0.00	0.00	0.04
0.30	0.00	26.73	0.00	0.00	0.00	0.00	0.00
0.40	0.00	26.84	0.00	0.00	0.00	0.00	0.00
0.50	0.00	26.96	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.07	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.19	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.30	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.41	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.53	0.00	0.00	0.00	0.00	0.00
1.10	0.00	27.64	0.00	0.00	0.00	0.00	0.00
1.20	0.00	27.76	0.00	0.00	0.00	0.00	0.00
1.30	0.00	27.87	0.00	0.00	0.00	0.00	0.00
1.40	0.00	27.99	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.10	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.21	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.33	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.44	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.55	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.67	0.00	0.00	0.00	0.00	0.00

Table 19: Put option prices for January Nino 3.4 SST conditioned on IRI ensemble forecasts released in September

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.75	23.77	0.02	0.58	0.84	1.00	1.00
-1.90	0.72	23.89	0.00	0.53	0.78	1.00	1.00
-1.80	0.68	24.02	0.00	0.48	0.72	0.96	1.00
-1.70	0.63	24.14	0.00	0.43	0.66	0.90	1.00
-1.60	0.59	24.27	0.00	0.38	0.60	0.84	1.00
-1.50	0.54	24.40	0.00	0.32	0.55	0.77	1.00
-1.40	0.49	24.52	0.00	0.27	0.49	0.71	1.00
-1.30	0.44	24.64	0.00	0.21	0.43	0.65	1.00
-1.20	0.39	24.77	0.00	0.15	0.37	0.59	1.00
-1.10	0.34	24.90	0.00	0.10	0.31	0.53	1.00
-1.00	0.30	25.02	0.00	0.05	0.26	0.47	0.95
-0.90	0.25	25.15	0.00	0.00	0.20	0.41	0.87
-0.80	0.21	25.27	0.00	0.00	0.14	0.35	0.80
-0.70	0.17	25.40	0.00	0.00	0.08	0.29	0.75
-0.60	0.14	25.52	0.00	0.00	0.03	0.23	0.67
-0.50	0.11	25.65	0.00	0.00	0.00	0.17	0.61
-0.40	0.08	25.77	0.00	0.00	0.00	0.11	0.55
-0.30	0.06	25.91	0.00	0.00	0.00	0.05	0.48
-0.20	0.05	26.03	0.00	0.00	0.00	0.00	0.43
-0.10	0.03	26.15	0.00	0.00	0.00	0.00	0.37
0.00	0.02	26.28	0.00	0.00	0.00	0.00	0.31
0.10	0.02	26.40	0.00	0.00	0.00	0.00	0.24
0.20	0.01	26.52	0.00	0.00	0.00	0.00	0.18
0.30	0.01	26.65	0.00	0.00	0.00	0.00	0.13
0.40	0.01	26.77	0.00	0.00	0.00	0.00	0.07
0.50	0.00	26.90	0.00	0.00	0.00	0.00	0.02
0.60	0.00	27.03	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.15	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.28	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.40	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.53	0.00	0.00	0.00	0.00	0.00
1.10	0.00	27.65	0.00	0.00	0.00	0.00	0.00
1.20	0.00	27.78	0.00	0.00	0.00	0.00	0.00
1.30	0.00	27.90	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.03	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.15	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.28	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.41	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.54	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.66	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.79	0.00	0.00	0.00	0.00	0.00

Table 20: Put option prices for January Nino 3.4 SST conditioned on IRI ensemble forecasts released in August

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.83	23.42	0.07	0.71	0.99	1.00	1.00
-1.90	0.80	23.56	0.02	0.66	0.93	1.00	1.00
-1.80	0.76	23.70	0.00	0.59	0.87	1.00	1.00
-1.70	0.72	23.84	0.00	0.54	0.80	1.00	1.00
-1.60	0.68	23.98	0.00	0.48	0.74	1.00	1.00
-1.50	0.64	24.12	0.00	0.42	0.67	0.93	1.00
-1.40	0.59	24.25	0.00	0.36	0.61	0.86	1.00
-1.30	0.54	24.40	0.00	0.30	0.54	0.79	1.00
-1.20	0.49	24.53	0.00	0.24	0.48	0.72	1.00
-1.10	0.43	24.67	0.00	0.18	0.42	0.66	1.00
-1.00	0.38	24.81	0.00	0.13	0.36	0.59	1.00
-0.90	0.33	24.95	0.00	0.06	0.29	0.52	1.00
-0.80	0.28	25.08	0.00	0.01	0.23	0.45	0.95
-0.70	0.23	25.22	0.00	0.00	0.16	0.38	0.88
-0.60	0.19	25.37	0.00	0.00	0.10	0.32	0.81
-0.50	0.15	25.50	0.00	0.00	0.04	0.25	0.73
-0.40	0.12	25.65	0.00	0.00	0.00	0.18	0.65
-0.30	0.09	25.78	0.00	0.00	0.00	0.11	0.59
-0.20	0.07	25.92	0.00	0.00	0.00	0.05	0.51
-0.10	0.05	26.06	0.00	0.00	0.00	0.00	0.45
0.00	0.04	26.19	0.00	0.00	0.00	0.00	0.38
0.10	0.03	26.33	0.00	0.00	0.00	0.00	0.31
0.20	0.02	26.48	0.00	0.00	0.00	0.00	0.25
0.30	0.01	26.61	0.00	0.00	0.00	0.00	0.18
0.40	0.01	26.75	0.00	0.00	0.00	0.00	0.13
0.50	0.01	26.89	0.00	0.00	0.00	0.00	0.07
0.60	0.00	27.03	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.17	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.31	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.45	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.58	0.00	0.00	0.00	0.00	0.00
1.10	0.00	27.73	0.00	0.00	0.00	0.00	0.00
1.20	0.00	27.86	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.00	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.15	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.28	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.42	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.56	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.70	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.83	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.97	0.00	0.00	0.00	0.00	0.00

Table 21: Put option prices for January Nino 3.4 SST conditioned on IRI ensemble forecasts released in July

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.86	23.02	0.00	0.82	1.00	1.00	1.00
-1.90	0.84	23.18	0.00	0.76	1.00	1.00	1.00
-1.80	0.81	23.34	0.00	0.70	1.00	1.00	1.00
-1.70	0.78	23.51	0.00	0.62	0.96	1.00	1.00
-1.60	0.75	23.66	0.00	0.56	0.88	1.00	1.00
-1.50	0.71	23.82	0.00	0.50	0.81	1.00	1.00
-1.40	0.66	23.98	0.00	0.43	0.74	1.00	1.00
-1.30	0.62	24.13	0.00	0.37	0.67	0.97	1.00
-1.20	0.57	24.30	0.00	0.30	0.59	0.88	1.00
-1.10	0.52	24.45	0.00	0.24	0.52	0.81	1.00
-1.00	0.46	24.61	0.00	0.17	0.45	0.72	1.00
-0.90	0.40	24.77	0.00	0.10	0.37	0.64	1.00
-0.80	0.35	24.93	0.00	0.04	0.30	0.56	1.00
-0.70	0.29	25.09	0.00	0.00	0.23	0.48	1.00
-0.60	0.24	25.24	0.00	0.00	0.15	0.41	0.99
-0.50	0.20	25.40	0.00	0.00	0.08	0.33	0.92
-0.40	0.16	25.56	0.00	0.00	0.01	0.26	0.82
-0.30	0.12	25.73	0.00	0.00	0.00	0.17	0.72
-0.20	0.09	25.88	0.00	0.00	0.00	0.10	0.66
-0.10	0.07	26.05	0.00	0.00	0.00	0.02	0.57
0.00	0.05	26.20	0.00	0.00	0.00	0.00	0.49
0.10	0.03	26.37	0.00	0.00	0.00	0.00	0.40
0.20	0.03	26.53	0.00	0.00	0.00	0.00	0.35
0.30	0.02	26.67	0.00	0.00	0.00	0.00	0.27
0.40	0.01	26.84	0.00	0.00	0.00	0.00	0.20
0.50	0.01	27.00	0.00	0.00	0.00	0.00	0.13
0.60	0.01	27.16	0.00	0.00	0.00	0.00	0.07
0.70	0.01	27.32	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.47	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.64	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.79	0.00	0.00	0.00	0.00	0.00
1.10	0.00	27.95	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.11	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.27	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.43	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.59	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.75	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.90	0.00	0.00	0.00	0.00	0.00
1.80	0.00	29.07	0.00	0.00	0.00	0.00	0.00
1.90	0.00	29.23	0.00	0.00	0.00	0.00	0.00
2.00	0.00	29.40	0.00	0.00	0.00	0.00	0.00

Table 22: Put option prices for January Nino 3.4 SST conditioned on IRI ensemble forecasts released in June

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.87	22.83	0.00	0.86	1.00	1.00	1.00
-1.90	0.85	23.02	0.00	0.79	1.00	1.00	1.00
-1.80	0.82	23.18	0.00	0.72	1.00	1.00	1.00
-1.70	0.79	23.35	0.00	0.65	1.00	1.00	1.00
-1.60	0.76	23.53	0.00	0.59	0.94	1.00	1.00
-1.50	0.73	23.70	0.00	0.52	0.87	1.00	1.00
-1.40	0.68	23.88	0.00	0.44	0.78	1.00	1.00
-1.30	0.64	24.05	0.00	0.38	0.71	1.00	1.00
-1.20	0.59	24.21	0.00	0.31	0.63	0.95	1.00
-1.10	0.53	24.39	0.00	0.24	0.55	0.86	1.00
-1.00	0.48	24.56	0.00	0.17	0.47	0.77	1.00
-0.90	0.42	24.73	0.00	0.10	0.39	0.69	1.00
-0.80	0.36	24.91	0.00	0.02	0.31	0.59	1.00
-0.70	0.30	25.08	0.00	0.00	0.23	0.51	1.00
-0.60	0.25	25.26	0.00	0.00	0.15	0.42	1.00
-0.50	0.20	25.43	0.00	0.00	0.07	0.34	0.94
-0.40	0.15	25.60	0.00	0.00	0.00	0.25	0.84
-0.30	0.12	25.78	0.00	0.00	0.00	0.17	0.75
-0.20	0.09	25.95	0.00	0.00	0.00	0.08	0.66
-0.10	0.06	26.12	0.00	0.00	0.00	0.00	0.57
0.00	0.05	26.29	0.00	0.00	0.00	0.00	0.48
0.10	0.03	26.46	0.00	0.00	0.00	0.00	0.41
0.20	0.02	26.63	0.00	0.00	0.00	0.00	0.33
0.30	0.02	26.81	0.00	0.00	0.00	0.00	0.24
0.40	0.01	26.98	0.00	0.00	0.00	0.00	0.17
0.50	0.01	27.15	0.00	0.00	0.00	0.00	0.11
0.60	0.01	27.33	0.00	0.00	0.00	0.00	0.04
0.70	0.01	27.50	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.67	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.85	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.02	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.19	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.36	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.54	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.71	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.88	0.00	0.00	0.00	0.00	0.00
1.60	0.00	29.06	0.00	0.00	0.00	0.00	0.00
1.70	0.00	29.22	0.00	0.00	0.00	0.00	0.00
1.80	0.00	29.40	0.00	0.00	0.00	0.00	0.00
1.90	0.00	29.57	0.00	0.00	0.00	0.00	0.00
2.00	0.00	29.74	0.00	0.00	0.00	0.00	0.00

Table 23: Put option prices for January Nino 3.4 SST conditioned on IRI ensemble forecasts released in May

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.87	22.33	0.00	0.94	1.00	1.00	1.00
-1.90	0.85	22.53	0.00	0.86	1.00	1.00	1.00
-1.80	0.83	22.73	0.00	0.79	1.00	1.00	1.00
-1.70	0.81	22.92	0.00	0.73	1.00	1.00	1.00
-1.60	0.79	23.12	0.00	0.64	1.00	1.00	1.00
-1.50	0.76	23.32	0.00	0.58	1.00	1.00	1.00
-1.40	0.73	23.51	0.00	0.51	0.95	1.00	1.00
-1.30	0.70	23.71	0.00	0.43	0.87	1.00	1.00
-1.20	0.65	23.91	0.00	0.35	0.77	1.00	1.00
-1.10	0.60	24.11	0.00	0.27	0.68	1.00	1.00
-1.00	0.55	24.30	0.00	0.21	0.59	0.97	1.00
-0.90	0.50	24.50	0.00	0.13	0.50	0.87	1.00
-0.80	0.44	24.71	0.00	0.04	0.40	0.76	1.00
-0.70	0.38	24.90	0.00	0.00	0.32	0.66	1.00
-0.60	0.32	25.10	0.00	0.00	0.23	0.56	1.00
-0.50	0.26	25.30	0.00	0.00	0.13	0.45	1.00
-0.40	0.21	25.50	0.00	0.00	0.04	0.35	1.00
-0.30	0.16	25.70	0.00	0.00	0.00	0.26	0.94
-0.20	0.12	25.89	0.00	0.00	0.00	0.15	0.82
-0.10	0.09	26.09	0.00	0.00	0.00	0.06	0.72
0.00	0.06	26.29	0.00	0.00	0.00	0.00	0.63
0.10	0.05	26.49	0.00	0.00	0.00	0.00	0.53
0.20	0.03	26.69	0.00	0.00	0.00	0.00	0.43
0.30	0.02	26.88	0.00	0.00	0.00	0.00	0.36
0.40	0.02	27.08	0.00	0.00	0.00	0.00	0.27
0.50	0.01	27.29	0.00	0.00	0.00	0.00	0.20
0.60	0.01	27.48	0.00	0.00	0.00	0.00	0.13
0.70	0.01	27.68	0.00	0.00	0.00	0.00	0.07
0.80	0.01	27.88	0.00	0.00	0.00	0.00	0.02
0.90	0.01	28.08	0.00	0.00	0.00	0.00	0.00
1.00	0.01	28.28	0.00	0.00	0.00	0.00	0.00
1.10	0.01	28.46	0.00	0.00	0.00	0.00	0.00
1.20	0.01	28.66	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.87	0.00	0.00	0.00	0.00	0.00
1.40	0.00	29.07	0.00	0.00	0.00	0.00	0.00
1.50	0.00	29.26	0.00	0.00	0.00	0.00	0.00
1.60	0.00	29.47	0.00	0.00	0.00	0.00	0.00
1.70	0.00	29.66	0.00	0.00	0.00	0.00	0.00
1.80	0.00	29.87	0.00	0.00	0.00	0.00	0.00
1.90	0.00	30.05	0.00	0.00	0.00	0.00	0.00
2.00	0.00	30.26	0.00	0.00	0.00	0.00	0.00

Table 24: Put option prices for January Nino 3.4 SST conditioned on IRI ensemble forecasts released in April

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.81	22.41	0.00	0.77	1.00	1.00	1.00
-1.90	0.80	22.60	0.00	0.71	1.00	1.00	1.00
-1.80	0.79	22.79	0.00	0.66	1.00	1.00	1.00
-1.70	0.77	22.98	0.00	0.59	1.00	1.00	1.00
-1.60	0.75	23.18	0.00	0.52	1.00	1.00	1.00
-1.50	0.72	23.37	0.00	0.46	1.00	1.00	1.00
-1.40	0.70	23.56	0.00	0.40	0.94	1.00	1.00
-1.30	0.66	23.74	0.00	0.33	0.85	1.00	1.00
-1.20	0.63	23.93	0.00	0.26	0.76	1.00	1.00
-1.10	0.59	24.12	0.00	0.20	0.67	1.00	1.00
-1.00	0.55	24.32	0.00	0.13	0.59	1.00	1.00
-0.90	0.50	24.50	0.00	0.06	0.51	0.94	1.00
-0.80	0.45	24.69	0.00	0.00	0.42	0.83	1.00
-0.70	0.40	24.88	0.00	0.00	0.33	0.73	1.00
-0.60	0.34	25.07	0.00	0.00	0.23	0.62	1.00
-0.50	0.29	25.25	0.00	0.00	0.15	0.52	1.00
-0.40	0.24	25.45	0.00	0.00	0.06	0.42	1.00
-0.30	0.19	25.63	0.00	0.00	0.00	0.32	1.00
-0.20	0.15	25.83	0.00	0.00	0.00	0.22	0.98
-0.10	0.12	26.02	0.00	0.00	0.00	0.13	0.86
0.00	0.09	26.21	0.00	0.00	0.00	0.04	0.75
0.10	0.07	26.39	0.00	0.00	0.00	0.00	0.68
0.20	0.05	26.58	0.00	0.00	0.00	0.00	0.60
0.30	0.04	26.78	0.00	0.00	0.00	0.00	0.50
0.40	0.03	26.97	0.00	0.00	0.00	0.00	0.43
0.50	0.02	27.16	0.00	0.00	0.00	0.00	0.36
0.60	0.02	27.35	0.00	0.00	0.00	0.00	0.30
0.70	0.02	27.54	0.00	0.00	0.00	0.00	0.25
0.80	0.01	27.73	0.00	0.00	0.00	0.00	0.22
0.90	0.01	27.92	0.00	0.00	0.00	0.00	0.18
1.00	0.01	28.10	0.00	0.00	0.00	0.00	0.13
1.10	0.01	28.30	0.00	0.00	0.00	0.00	0.09
1.20	0.01	28.48	0.00	0.00	0.00	0.00	0.08
1.30	0.01	28.68	0.00	0.00	0.00	0.00	0.07
1.40	0.01	28.86	0.00	0.00	0.00	0.00	0.03
1.50	0.01	29.06	0.00	0.00	0.00	0.00	0.00
1.60	0.01	29.25	0.00	0.00	0.00	0.00	0.00
1.70	0.01	29.43	0.00	0.00	0.00	0.00	0.00
1.80	0.01	29.63	0.00	0.00	0.00	0.00	0.00
1.90	0.01	29.82	0.00	0.00	0.00	0.00	0.00
2.00	0.01	30.01	0.00	0.00	0.00	0.00	0.00

Table 25: Put option prices for January Nino 3.4 SST conditioned on IRI ensemble forecasts released in March

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.67	23.08	0.00	0.18	1.00	1.00	1.00
-1.90	0.66	23.24	0.00	0.14	1.00	1.00	1.00
-1.80	0.65	23.40	0.00	0.10	1.00	1.00	1.00
-1.70	0.63	23.57	0.00	0.07	0.93	1.00	1.00
-1.60	0.61	23.73	0.00	0.04	0.85	1.00	1.00
-1.50	0.59	23.89	0.00	0.01	0.78	1.00	1.00
-1.40	0.57	24.06	0.00	0.00	0.70	1.00	1.00
-1.30	0.55	24.21	0.00	0.00	0.63	1.00	1.00
-1.20	0.52	24.39	0.00	0.00	0.55	1.00	1.00
-1.10	0.49	24.55	0.00	0.00	0.47	1.00	1.00
-1.00	0.45	24.72	0.00	0.00	0.39	0.99	1.00
-0.90	0.42	24.87	0.00	0.00	0.33	0.89	1.00
-0.80	0.38	25.05	0.00	0.00	0.25	0.77	1.00
-0.70	0.34	25.20	0.00	0.00	0.18	0.68	1.00
-0.60	0.30	25.37	0.00	0.00	0.10	0.57	1.00
-0.50	0.25	25.54	0.00	0.00	0.02	0.46	1.00
-0.40	0.22	25.69	0.00	0.00	0.00	0.38	1.00
-0.30	0.18	25.86	0.00	0.00	0.00	0.27	1.00
-0.20	0.15	26.01	0.00	0.00	0.00	0.19	1.00
-0.10	0.12	26.19	0.00	0.00	0.00	0.10	0.97
0.00	0.10	26.33	0.00	0.00	0.00	0.03	0.89
0.10	0.08	26.50	0.00	0.00	0.00	0.00	0.81
0.20	0.07	26.67	0.00	0.00	0.00	0.00	0.78
0.30	0.06	26.84	0.00	0.00	0.00	0.00	0.70
0.40	0.05	26.99	0.00	0.00	0.00	0.00	0.71
0.50	0.05	27.17	0.00	0.00	0.00	0.00	0.70
0.60	0.05	27.32	0.00	0.00	0.00	0.00	0.71
0.70	0.05	27.49	0.00	0.00	0.00	0.00	0.71
0.80	0.05	27.66	0.00	0.00	0.00	0.00	0.73
0.90	0.05	27.82	0.00	0.00	0.00	0.00	0.76
1.00	0.05	27.98	0.00	0.00	0.00	0.00	0.79
1.10	0.05	28.14	0.00	0.00	0.00	0.00	0.86
1.20	0.05	28.30	0.00	0.00	0.00	0.00	0.88
1.30	0.05	28.47	0.00	0.00	0.00	0.00	0.92
1.40	0.06	28.63	0.00	0.00	0.00	0.00	0.97
1.50	0.06	28.80	0.00	0.00	0.00	0.00	1.00
1.60	0.06	28.96	0.00	0.00	0.00	0.00	1.00
1.70	0.06	29.13	0.00	0.00	0.00	0.00	1.00
1.80	0.06	29.29	0.00	0.00	0.00	0.00	1.00
1.90	0.06	29.45	0.00	0.00	0.00	0.00	1.00
2.00	0.06	29.62	0.00	0.00	0.00	0.00	1.00

Appendix E: February Pricing

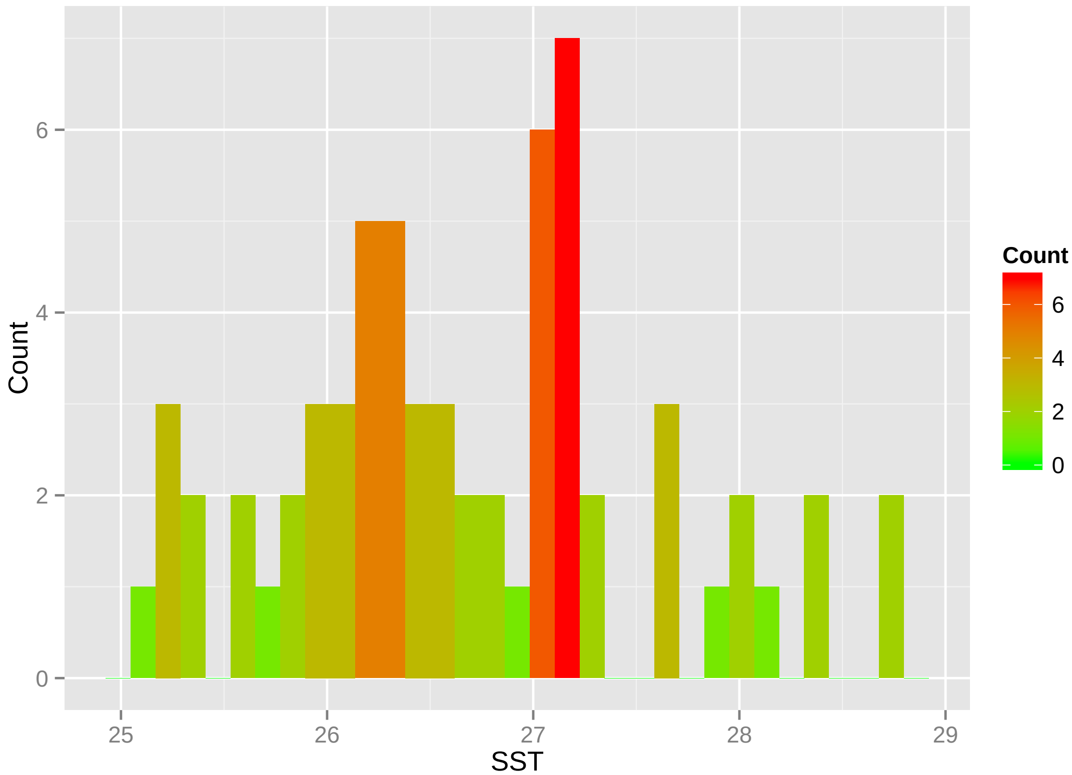


Figure 31: Histogram of February SST for Niño 3.4 ERSST.3b

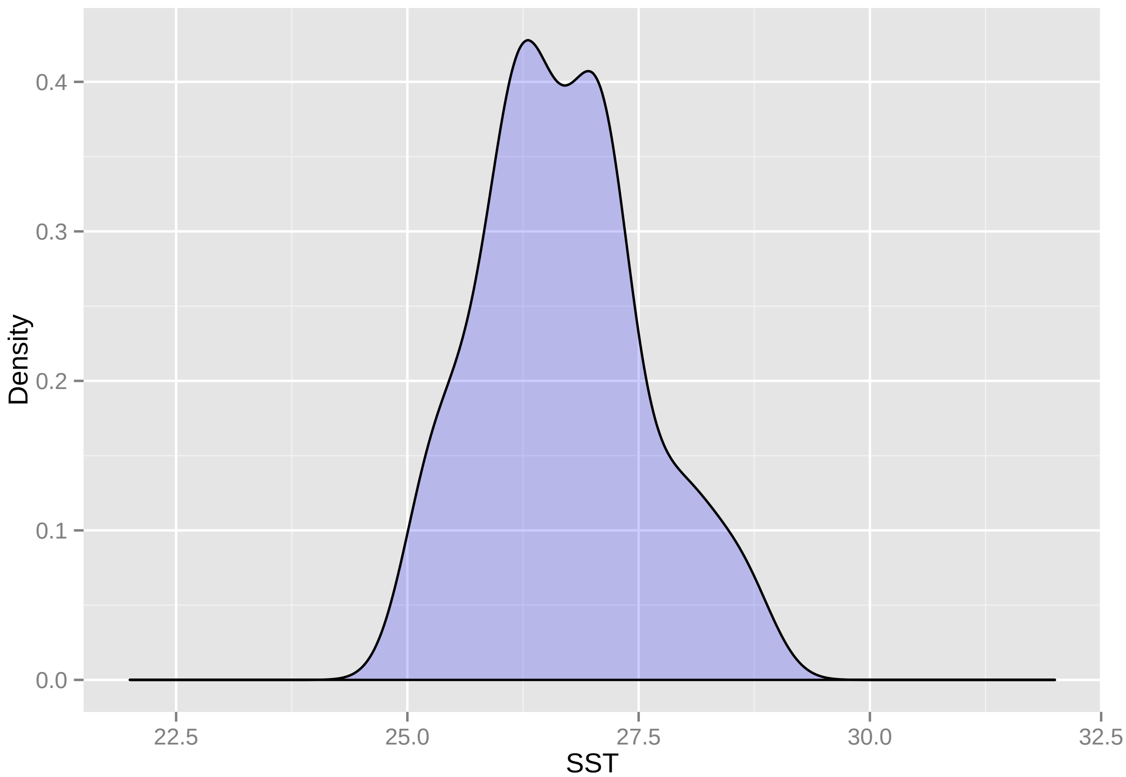


Figure 32: Kernel density estimate of February SST for Niño 3.4 ERSST.3b

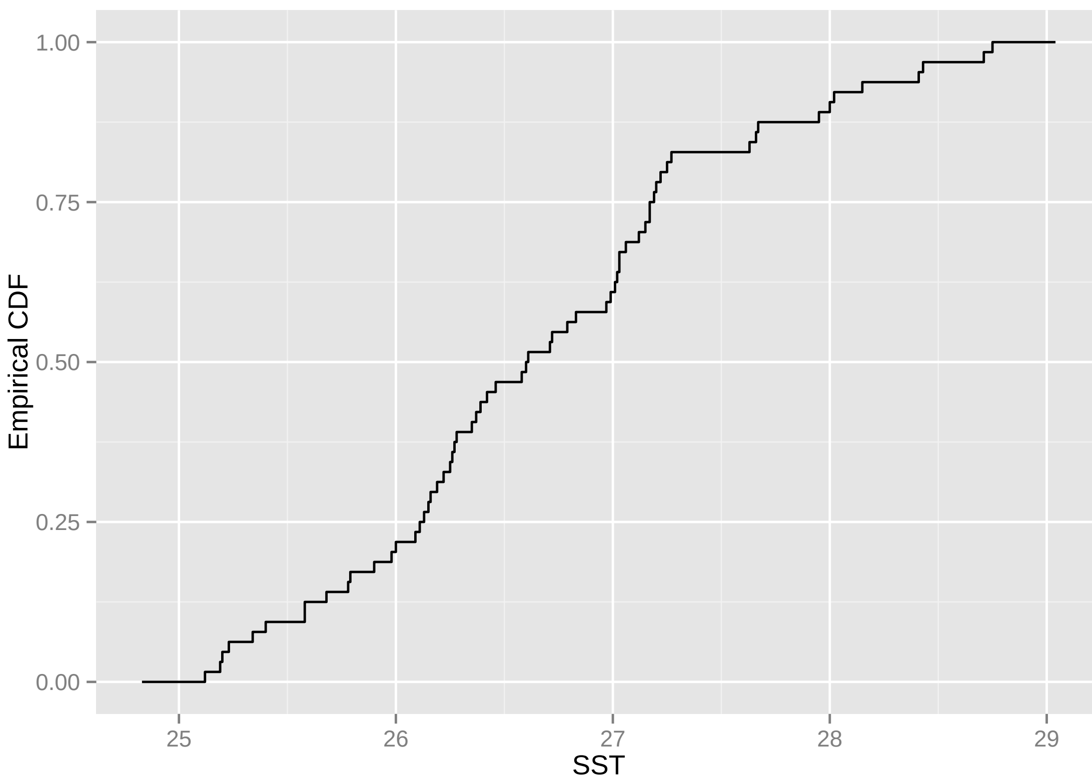


Figure 33: ECDF of February SST for Niño 3.4 ERSST.3b

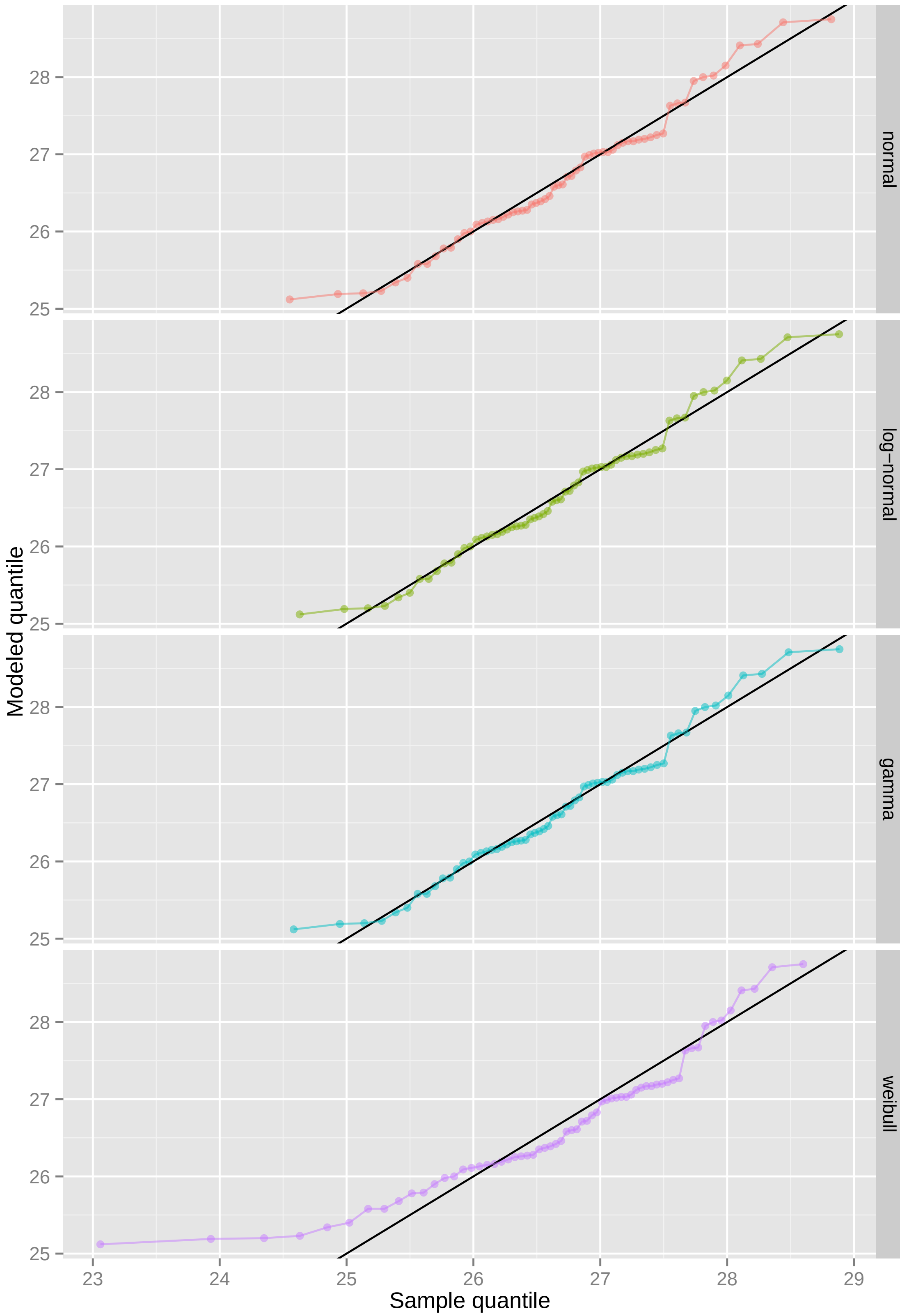


Figure 34: QQ plots of February SST for Niño 3.4 ERSST.3b compared to samples from various distributions (n=2 million)

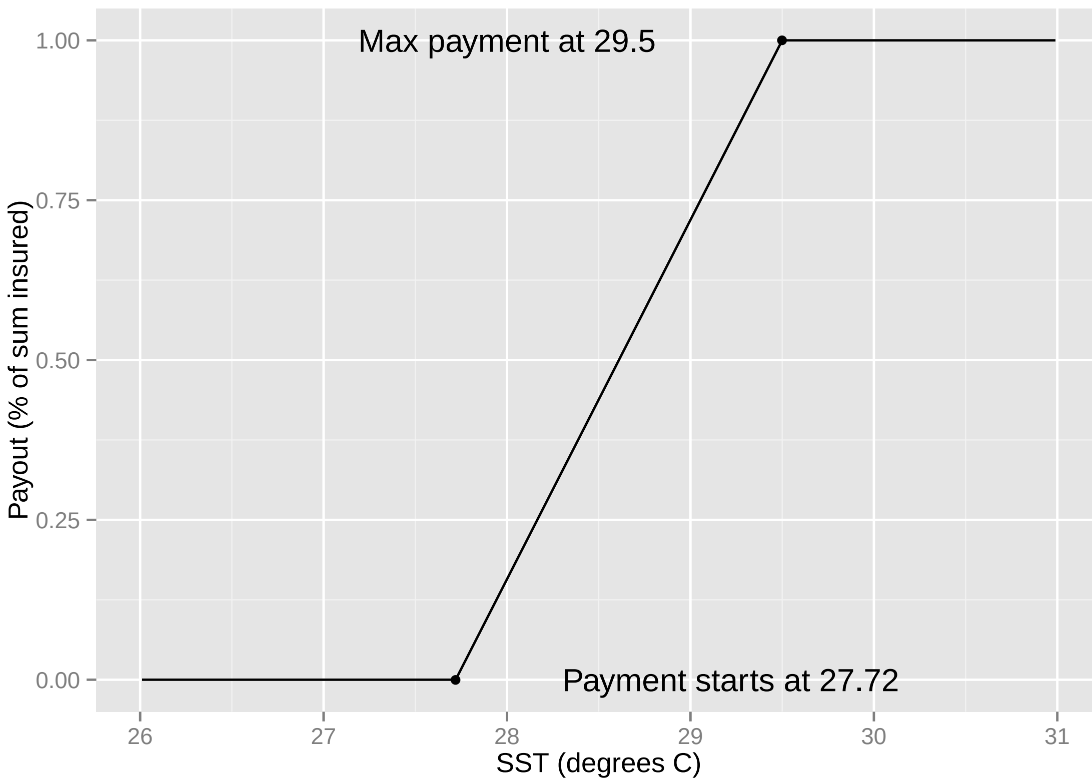


Figure 35: Payout function for call option on February SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations above the baseline

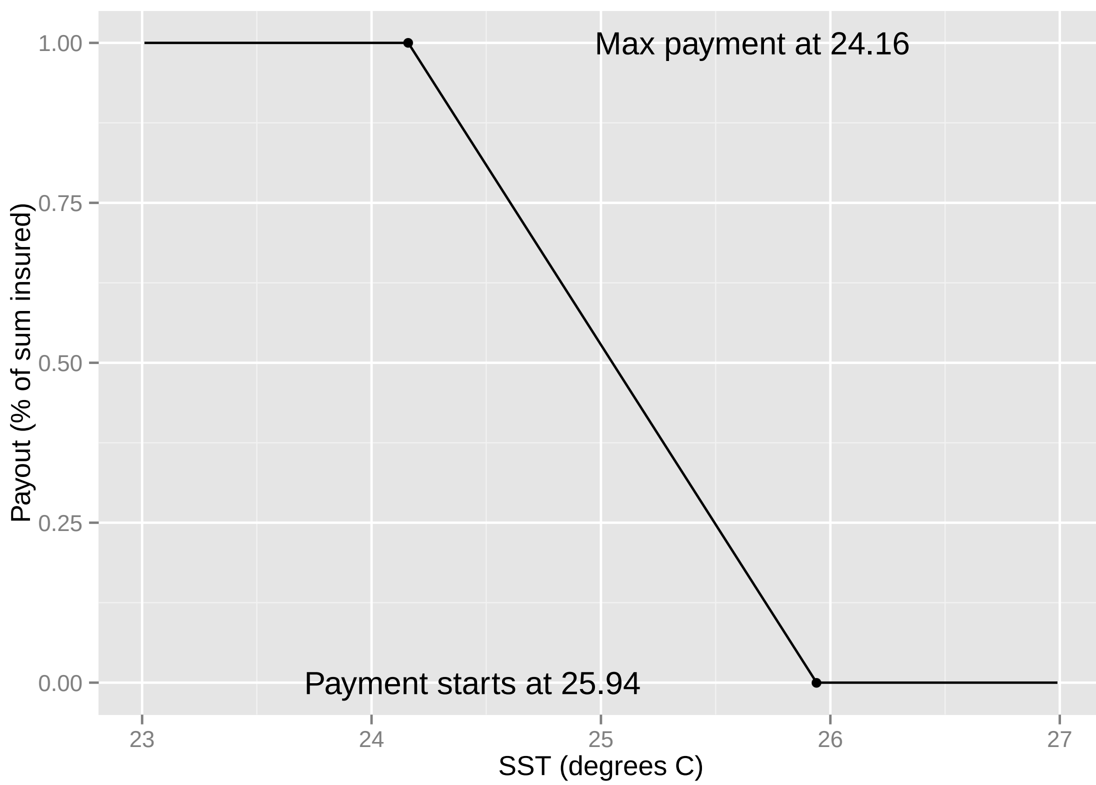


Figure 36: Payout function for put option on February SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

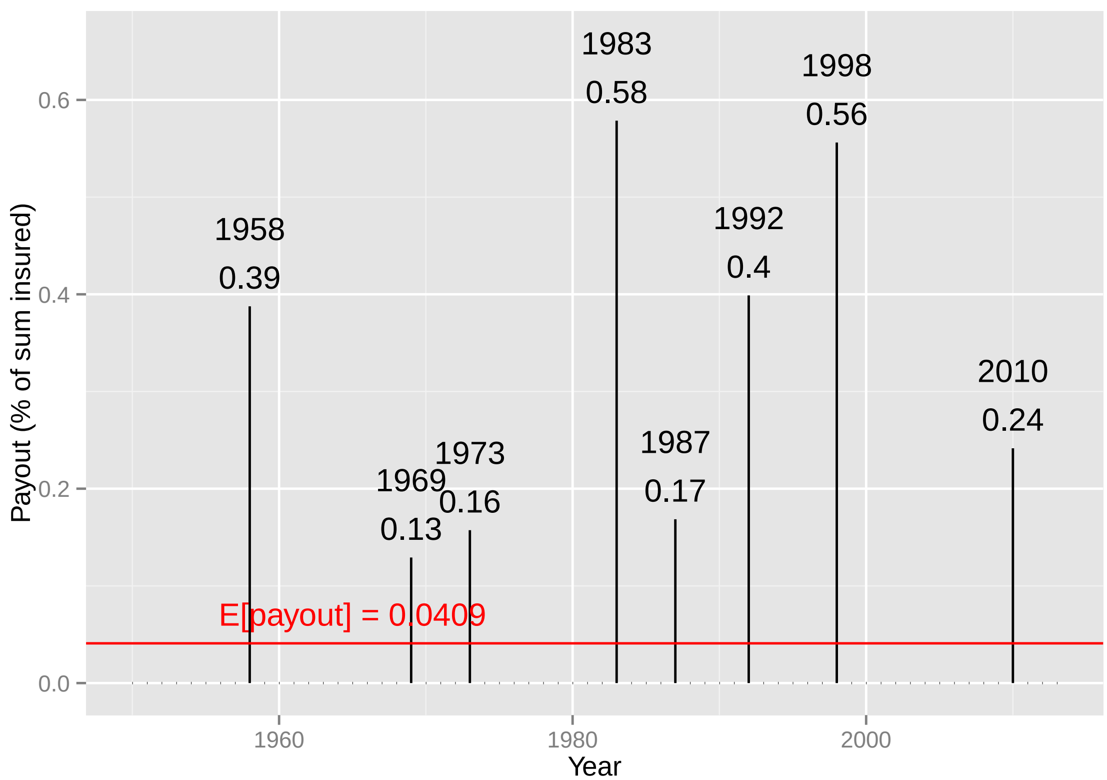


Figure 37: Historical burn on call option for February SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations above the baseline

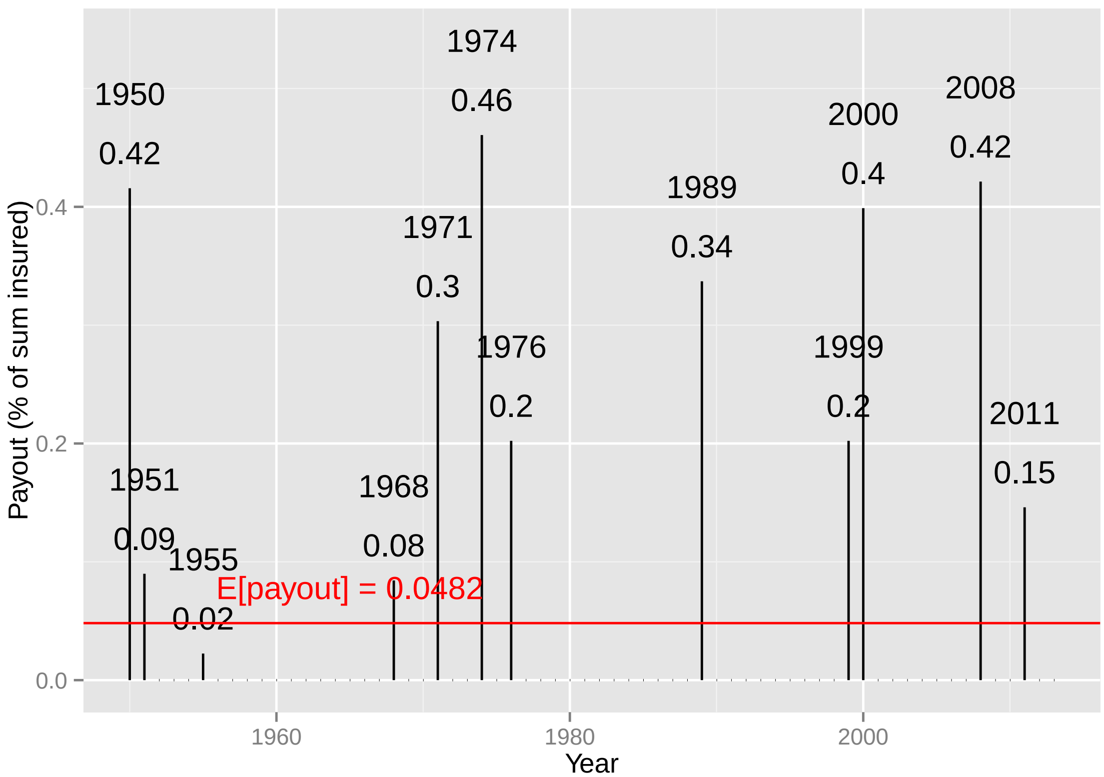


Figure 38: Historical burn on put option on February SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

Table 26: Bayesian regression linking February Niño 3.4 SST anomalies to average of relevant IRI ensemble forecasts

	mean	sd	2.5$^{\text{th}}$ q	25$^{\text{th}}$ q	50$^{\text{th}}$ q	75$^{\text{th}}$ q	97.5$^{\text{th}}$ q	n_eff	Rhat
December forecast average covering February Niño 3.4 SST anomalies									
α	-0.20	0.10	-0.40	-0.30	-0.20	-0.20	0.00	96367	1
β	0.90	0.10	0.70	0.80	0.90	1.00	1.10	92877	1
σ_y^2	0.10	0.10	0.00	0.10	0.10	0.10	0.30	52061	1
November forecast average covering February Niño 3.4 SST anomalies									
α	-0.30	0.10	-0.50	-0.40	-0.30	-0.20	0.00	95846	1
β	0.90	0.20	0.60	0.80	0.90	1.00	1.20	95119	1
σ_y^2	0.20	0.10	0.10	0.10	0.20	0.20	0.50	55661	1
October forecast average covering February Niño 3.4 SST anomalies									
α	-0.30	0.20	-0.60	-0.40	-0.30	-0.20	0.00	94716	1
β	1.00	0.20	0.60	0.90	1.00	1.10	1.40	96008	1
σ_y^2	0.30	0.20	0.10	0.20	0.20	0.30	0.70	58344	1
September forecast average covering February Niño 3.4 SST anomalies									
α	-0.40	0.20	-0.80	-0.50	-0.40	-0.30	0.00	91313	1
β	1.10	0.30	0.60	0.90	1.10	1.30	1.70	85884	1
σ_y^2	0.30	0.20	0.10	0.20	0.30	0.40	0.90	56890	1
August forecast average covering February Niño 3.4 SST anomalies									
α	-0.40	0.20	-0.80	-0.60	-0.40	-0.30	-0.10	91450	1
β	1.30	0.30	0.60	1.10	1.30	1.50	1.90	87072	1
σ_y^2	0.30	0.20	0.10	0.20	0.30	0.40	0.90	56251	1
July forecast average covering February Niño 3.4 SST anomalies									
α	-0.40	0.20	-0.90	-0.60	-0.40	-0.30	0.00	93476	1
β	1.50	0.40	0.60	1.20	1.50	1.80	2.40	89662	1
σ_y^2	0.40	0.30	0.10	0.20	0.30	0.50	1.30	54311	1
June forecast average covering February Niño 3.4 SST anomalies									
α	-0.40	0.20	-0.80	-0.50	-0.40	-0.20	0.10	94941	1
β	1.50	0.50	0.50	1.20	1.50	1.80	2.50	91166	1
σ_y^2	0.50	0.30	0.20	0.30	0.40	0.60	1.30	56903	1
May forecast average covering February Niño 3.4 SST anomalies									
α	-0.40	0.20	-0.90	-0.50	-0.40	-0.20	0.10	91609	1
β	1.70	0.70	0.30	1.30	1.70	2.10	3.00	88744	1
σ_y^2	0.60	0.40	0.20	0.40	0.50	0.70	1.70	55369	1
April forecast average covering February Niño 3.4 SST anomalies									
α	-0.40	0.30	-1.00	-0.60	-0.50	-0.30	0.10	86245	1
β	1.50	0.80	0.00	1.00	1.50	2.00	3.00	81749	1
σ_y^2	0.80	0.50	0.30	0.40	0.60	0.90	2.00	55026	1

Table 27: Call option prices for February Nino 3.4 SST conditioned on IRI ensemble forecasts released in December

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	24.83	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	24.92	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	25.00	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	25.09	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	25.18	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	25.27	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	25.36	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	25.45	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	25.54	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.63	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.72	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.81	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.90	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.99	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	26.07	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	26.16	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.25	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.35	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.43	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	26.52	0.00	0.00	0.00	0.00	0.00
0.00	0.00	26.61	0.00	0.00	0.00	0.00	0.00
0.10	0.00	26.70	0.00	0.00	0.00	0.00	0.00
0.20	0.00	26.79	0.00	0.00	0.00	0.00	0.00
0.30	0.00	26.88	0.00	0.00	0.00	0.00	0.00
0.40	0.00	26.97	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.06	0.00	0.00	0.00	0.00	0.04
0.60	0.01	27.15	0.00	0.00	0.00	0.00	0.10
0.70	0.01	27.24	0.00	0.00	0.00	0.00	0.15
0.80	0.02	27.33	0.00	0.00	0.00	0.00	0.21
0.90	0.02	27.42	0.00	0.00	0.00	0.00	0.25
1.00	0.04	27.51	0.00	0.00	0.00	0.01	0.31
1.10	0.05	27.60	0.00	0.00	0.00	0.06	0.36
1.20	0.07	27.68	0.00	0.00	0.00	0.11	0.43
1.30	0.10	27.77	0.00	0.00	0.03	0.17	0.47
1.40	0.13	27.86	0.00	0.00	0.08	0.22	0.53
1.50	0.17	27.95	0.00	0.00	0.13	0.27	0.59
1.60	0.21	28.04	0.00	0.04	0.18	0.32	0.64
1.70	0.25	28.13	0.00	0.09	0.23	0.37	0.70
1.80	0.30	28.22	0.00	0.14	0.28	0.43	0.75
1.90	0.34	28.31	0.00	0.18	0.33	0.48	0.81
2.00	0.39	28.40	0.00	0.23	0.38	0.53	0.87

Table 28: Call option prices for February Nino 3.4 SST conditioned on IRI ensemble forecasts released in November

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	24.72	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	24.81	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.91	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	25.00	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	25.09	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	25.18	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	25.28	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	25.37	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	25.46	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.55	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.64	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.73	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.83	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.92	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	26.01	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	26.11	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.19	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.29	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.38	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	26.48	0.00	0.00	0.00	0.00	0.00
0.00	0.00	26.57	0.00	0.00	0.00	0.00	0.00
0.10	0.00	26.66	0.00	0.00	0.00	0.00	0.00
0.20	0.00	26.75	0.00	0.00	0.00	0.00	0.00
0.30	0.00	26.84	0.00	0.00	0.00	0.00	0.03
0.40	0.01	26.93	0.00	0.00	0.00	0.00	0.09
0.50	0.01	27.03	0.00	0.00	0.00	0.00	0.14
0.60	0.01	27.12	0.00	0.00	0.00	0.00	0.20
0.70	0.02	27.21	0.00	0.00	0.00	0.00	0.25
0.80	0.03	27.30	0.00	0.00	0.00	0.00	0.30
0.90	0.04	27.39	0.00	0.00	0.00	0.00	0.36
1.00	0.05	27.49	0.00	0.00	0.00	0.04	0.42
1.10	0.07	27.58	0.00	0.00	0.00	0.09	0.48
1.20	0.09	27.67	0.00	0.00	0.00	0.14	0.54
1.30	0.12	27.76	0.00	0.00	0.02	0.20	0.60
1.40	0.15	27.85	0.00	0.00	0.07	0.25	0.66
1.50	0.19	27.94	0.00	0.00	0.13	0.31	0.71
1.60	0.23	28.04	0.00	0.00	0.18	0.36	0.77
1.70	0.27	28.13	0.00	0.05	0.23	0.42	0.84
1.80	0.31	28.22	0.00	0.09	0.28	0.47	0.90
1.90	0.35	28.32	0.00	0.14	0.33	0.53	0.96
2.00	0.40	28.41	0.00	0.19	0.38	0.58	1.00

Table 29: Call option prices for February Nino 3.4 SST conditioned on IRI ensemble forecasts released in October

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	24.54	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	24.64	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.74	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.84	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.94	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	25.04	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	25.14	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	25.24	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	25.34	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.44	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.53	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.63	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.73	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.83	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.92	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	26.03	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.13	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.23	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.32	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	26.42	0.00	0.00	0.00	0.00	0.00
0.00	0.00	26.52	0.00	0.00	0.00	0.00	0.00
0.10	0.00	26.62	0.00	0.00	0.00	0.00	0.00
0.20	0.01	26.72	0.00	0.00	0.00	0.00	0.05
0.30	0.01	26.81	0.00	0.00	0.00	0.00	0.10
0.40	0.01	26.91	0.00	0.00	0.00	0.00	0.17
0.50	0.02	27.02	0.00	0.00	0.00	0.00	0.23
0.60	0.02	27.11	0.00	0.00	0.00	0.00	0.28
0.70	0.03	27.21	0.00	0.00	0.00	0.00	0.34
0.80	0.04	27.31	0.00	0.00	0.00	0.00	0.40
0.90	0.06	27.41	0.00	0.00	0.00	0.02	0.47
1.00	0.07	27.51	0.00	0.00	0.00	0.08	0.53
1.10	0.10	27.60	0.00	0.00	0.00	0.13	0.60
1.20	0.12	27.70	0.00	0.00	0.00	0.19	0.65
1.30	0.15	27.80	0.00	0.00	0.04	0.25	0.72
1.40	0.19	27.90	0.00	0.00	0.10	0.31	0.79
1.50	0.23	28.00	0.00	0.00	0.16	0.37	0.85
1.60	0.27	28.10	0.00	0.00	0.21	0.43	0.92
1.70	0.31	28.19	0.00	0.05	0.27	0.48	0.99
1.80	0.35	28.29	0.00	0.10	0.32	0.55	1.00
1.90	0.40	28.39	0.00	0.15	0.38	0.61	1.00
2.00	0.44	28.49	0.00	0.20	0.43	0.67	1.00

Table 30: Call option prices for February Nino 3.4 SST conditioned on IRI ensemble forecasts released in September

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	24.21	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	24.32	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.44	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.55	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.66	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.77	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	24.89	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	25.00	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	25.10	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.21	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.33	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.44	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.55	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.66	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.77	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	25.89	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	25.99	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.10	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.22	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	26.33	0.00	0.00	0.00	0.00	0.00
0.00	0.00	26.44	0.00	0.00	0.00	0.00	0.00
0.10	0.01	26.55	0.00	0.00	0.00	0.00	0.02
0.20	0.01	26.66	0.00	0.00	0.00	0.00	0.08
0.30	0.01	26.78	0.00	0.00	0.00	0.00	0.15
0.40	0.01	26.88	0.00	0.00	0.00	0.00	0.22
0.50	0.02	27.00	0.00	0.00	0.00	0.00	0.29
0.60	0.03	27.10	0.00	0.00	0.00	0.00	0.34
0.70	0.04	27.21	0.00	0.00	0.00	0.00	0.41
0.80	0.05	27.32	0.00	0.00	0.00	0.00	0.50
0.90	0.07	27.43	0.00	0.00	0.00	0.06	0.55
1.00	0.10	27.55	0.00	0.00	0.00	0.13	0.64
1.10	0.12	27.66	0.00	0.00	0.00	0.19	0.71
1.20	0.16	27.77	0.00	0.00	0.03	0.26	0.78
1.30	0.19	27.88	0.00	0.00	0.09	0.33	0.85
1.40	0.24	27.99	0.00	0.00	0.15	0.39	0.93
1.50	0.28	28.10	0.00	0.00	0.21	0.46	1.00
1.60	0.33	28.21	0.00	0.03	0.28	0.53	1.00
1.70	0.38	28.33	0.00	0.09	0.34	0.60	1.00
1.80	0.42	28.43	0.00	0.14	0.40	0.66	1.00
1.90	0.47	28.55	0.00	0.20	0.46	0.73	1.00
2.00	0.52	28.66	0.00	0.26	0.53	0.80	1.00

Table 31: Call option prices for February Nino 3.4 SST conditioned on IRI ensemble forecasts released in August

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	23.86	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	23.99	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.11	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.24	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.37	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.49	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	24.62	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	24.74	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	24.87	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.00	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.12	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.25	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.37	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.51	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.62	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	25.75	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	25.88	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.00	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.13	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	26.26	0.00	0.00	0.00	0.00	0.00
0.00	0.00	26.38	0.00	0.00	0.00	0.00	0.00
0.10	0.01	26.51	0.00	0.00	0.00	0.00	0.01
0.20	0.01	26.64	0.00	0.00	0.00	0.00	0.08
0.30	0.01	26.76	0.00	0.00	0.00	0.00	0.15
0.40	0.02	26.89	0.00	0.00	0.00	0.00	0.22
0.50	0.02	27.02	0.00	0.00	0.00	0.00	0.31
0.60	0.03	27.14	0.00	0.00	0.00	0.00	0.37
0.70	0.05	27.26	0.00	0.00	0.00	0.00	0.45
0.80	0.06	27.39	0.00	0.00	0.00	0.03	0.54
0.90	0.09	27.52	0.00	0.00	0.00	0.11	0.62
1.00	0.12	27.65	0.00	0.00	0.00	0.19	0.71
1.10	0.16	27.77	0.00	0.00	0.03	0.26	0.78
1.20	0.20	27.90	0.00	0.00	0.10	0.34	0.86
1.30	0.25	28.02	0.00	0.00	0.17	0.41	0.95
1.40	0.30	28.15	0.00	0.00	0.24	0.49	1.00
1.50	0.35	28.27	0.00	0.06	0.31	0.56	1.00
1.60	0.41	28.40	0.00	0.12	0.38	0.64	1.00
1.70	0.46	28.52	0.00	0.19	0.45	0.71	1.00
1.80	0.52	28.65	0.00	0.25	0.52	0.79	1.00
1.90	0.57	28.78	0.00	0.32	0.59	0.87	1.00
2.00	0.62	28.90	0.00	0.38	0.67	0.95	1.00

Table 32: Call option prices for February Nino 3.4 SST conditioned on IRI ensemble forecasts released in July

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	23.40	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	23.55	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	23.69	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	23.85	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	23.99	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.14	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	24.29	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	24.44	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	24.59	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	24.74	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	24.89	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.04	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.19	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.34	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.48	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	25.64	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	25.79	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	25.93	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.08	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	26.24	0.00	0.00	0.00	0.00	0.00
0.00	0.01	26.38	0.00	0.00	0.00	0.00	0.02
0.10	0.01	26.53	0.00	0.00	0.00	0.00	0.11
0.20	0.01	26.68	0.00	0.00	0.00	0.00	0.19
0.30	0.02	26.83	0.00	0.00	0.00	0.00	0.28
0.40	0.03	26.98	0.00	0.00	0.00	0.00	0.37
0.50	0.04	27.13	0.00	0.00	0.00	0.00	0.46
0.60	0.06	27.28	0.00	0.00	0.00	0.00	0.56
0.70	0.09	27.43	0.00	0.00	0.00	0.09	0.66
0.80	0.12	27.58	0.00	0.00	0.00	0.18	0.77
0.90	0.16	27.73	0.00	0.00	0.01	0.27	0.87
1.00	0.21	27.88	0.00	0.00	0.09	0.36	0.97
1.10	0.27	28.04	0.00	0.00	0.18	0.45	1.00
1.20	0.33	28.18	0.00	0.00	0.26	0.54	1.00
1.30	0.38	28.32	0.00	0.05	0.34	0.63	1.00
1.40	0.44	28.47	0.00	0.13	0.42	0.72	1.00
1.50	0.51	28.63	0.00	0.20	0.51	0.82	1.00
1.60	0.56	28.78	0.00	0.28	0.59	0.91	1.00
1.70	0.62	28.92	0.00	0.35	0.68	1.00	1.00
1.80	0.67	29.07	0.00	0.42	0.76	1.00	1.00
1.90	0.71	29.22	0.00	0.49	0.84	1.00	1.00
2.00	0.75	29.37	0.00	0.57	0.93	1.00	1.00

Table 33: Call option prices for February Nino 3.4 SST conditioned on IRI ensemble forecasts released in June

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	23.39	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	23.54	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	23.70	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	23.85	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.00	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.15	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	24.30	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	24.46	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	24.61	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	24.77	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	24.92	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.07	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.22	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.38	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.53	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	25.68	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	25.84	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	25.99	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.14	0.00	0.00	0.00	0.00	0.00
-0.10	0.01	26.29	0.00	0.00	0.00	0.00	0.02
0.00	0.01	26.45	0.00	0.00	0.00	0.00	0.11
0.10	0.01	26.60	0.00	0.00	0.00	0.00	0.19
0.20	0.02	26.75	0.00	0.00	0.00	0.00	0.27
0.30	0.03	26.90	0.00	0.00	0.00	0.00	0.36
0.40	0.04	27.06	0.00	0.00	0.00	0.00	0.45
0.50	0.06	27.21	0.00	0.00	0.00	0.00	0.56
0.60	0.08	27.36	0.00	0.00	0.00	0.06	0.65
0.70	0.11	27.52	0.00	0.00	0.00	0.15	0.76
0.80	0.16	27.67	0.00	0.00	0.00	0.25	0.87
0.90	0.20	27.82	0.00	0.00	0.05	0.34	0.98
1.00	0.25	27.98	0.00	0.00	0.14	0.43	1.00
1.10	0.31	28.13	0.00	0.00	0.23	0.53	1.00
1.20	0.37	28.28	0.00	0.01	0.32	0.62	1.00
1.30	0.43	28.43	0.00	0.08	0.40	0.72	1.00
1.40	0.49	28.58	0.00	0.15	0.48	0.81	1.00
1.50	0.55	28.74	0.00	0.23	0.57	0.92	1.00
1.60	0.60	28.90	0.00	0.31	0.66	1.00	1.00
1.70	0.65	29.04	0.00	0.38	0.74	1.00	1.00
1.80	0.70	29.20	0.00	0.45	0.83	1.00	1.00
1.90	0.74	29.35	0.00	0.52	0.92	1.00	1.00
2.00	0.77	29.50	0.00	0.59	1.00	1.00	1.00

Table 34: Call option prices for February Nino 3.4 SST conditioned on IRI ensemble forecasts released in May

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	23.14	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	23.30	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	23.47	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	23.63	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	23.80	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	23.97	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	24.13	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	24.30	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	24.46	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	24.64	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	24.80	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	24.97	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.13	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.30	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.47	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	25.63	0.00	0.00	0.00	0.00	0.00
-0.40	0.01	25.80	0.00	0.00	0.00	0.00	0.00
-0.30	0.01	25.96	0.00	0.00	0.00	0.00	0.00
-0.20	0.01	26.13	0.00	0.00	0.00	0.00	0.07
-0.10	0.01	26.30	0.00	0.00	0.00	0.00	0.14
0.00	0.01	26.46	0.00	0.00	0.00	0.00	0.21
0.10	0.02	26.63	0.00	0.00	0.00	0.00	0.32
0.20	0.03	26.79	0.00	0.00	0.00	0.00	0.40
0.30	0.04	26.96	0.00	0.00	0.00	0.00	0.51
0.40	0.06	27.13	0.00	0.00	0.00	0.00	0.63
0.50	0.09	27.29	0.00	0.00	0.00	0.05	0.72
0.60	0.12	27.45	0.00	0.00	0.00	0.16	0.85
0.70	0.17	27.63	0.00	0.00	0.00	0.26	0.97
0.80	0.21	27.79	0.00	0.00	0.04	0.37	1.00
0.90	0.27	27.95	0.00	0.00	0.13	0.47	1.00
1.00	0.32	28.12	0.00	0.00	0.22	0.57	1.00
1.10	0.38	28.28	0.00	0.00	0.31	0.68	1.00
1.20	0.45	28.46	0.00	0.03	0.41	0.79	1.00
1.30	0.50	28.62	0.00	0.11	0.51	0.90	1.00
1.40	0.56	28.78	0.00	0.18	0.60	1.00	1.00
1.50	0.61	28.96	0.00	0.27	0.70	1.00	1.00
1.60	0.65	29.12	0.00	0.34	0.79	1.00	1.00
1.70	0.69	29.28	0.00	0.41	0.88	1.00	1.00
1.80	0.73	29.45	0.00	0.49	0.97	1.00	1.00
1.90	0.76	29.61	0.00	0.56	1.00	1.00	1.00
2.00	0.79	29.78	0.00	0.64	1.00	1.00	1.00

Table 35: Call option prices for February Nino 3.4 SST conditioned on IRI ensemble forecasts released in April

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.01	23.38	0.00	0.00	0.00	0.00	0.00
-1.90	0.01	23.52	0.00	0.00	0.00	0.00	0.00
-1.80	0.01	23.68	0.00	0.00	0.00	0.00	0.00
-1.70	0.01	23.83	0.00	0.00	0.00	0.00	0.00
-1.60	0.01	23.97	0.00	0.00	0.00	0.00	0.00
-1.50	0.01	24.12	0.00	0.00	0.00	0.00	0.00
-1.40	0.01	24.28	0.00	0.00	0.00	0.00	0.00
-1.30	0.01	24.42	0.00	0.00	0.00	0.00	0.00
-1.20	0.01	24.58	0.00	0.00	0.00	0.00	0.00
-1.10	0.01	24.72	0.00	0.00	0.00	0.00	0.00
-1.00	0.01	24.88	0.00	0.00	0.00	0.00	0.00
-0.90	0.01	25.02	0.00	0.00	0.00	0.00	0.00
-0.80	0.01	25.18	0.00	0.00	0.00	0.00	0.00
-0.70	0.01	25.33	0.00	0.00	0.00	0.00	0.00
-0.60	0.01	25.48	0.00	0.00	0.00	0.00	0.00
-0.50	0.01	25.64	0.00	0.00	0.00	0.00	0.00
-0.40	0.01	25.79	0.00	0.00	0.00	0.00	0.04
-0.30	0.01	25.94	0.00	0.00	0.00	0.00	0.10
-0.20	0.01	26.08	0.00	0.00	0.00	0.00	0.15
-0.10	0.01	26.23	0.00	0.00	0.00	0.00	0.21
0.00	0.02	26.38	0.00	0.00	0.00	0.00	0.27
0.10	0.02	26.53	0.00	0.00	0.00	0.00	0.35
0.20	0.03	26.68	0.00	0.00	0.00	0.00	0.44
0.30	0.04	26.84	0.00	0.00	0.00	0.00	0.53
0.40	0.06	26.98	0.00	0.00	0.00	0.00	0.61
0.50	0.08	27.14	0.00	0.00	0.00	0.00	0.73
0.60	0.11	27.28	0.00	0.00	0.00	0.09	0.83
0.70	0.14	27.44	0.00	0.00	0.00	0.18	0.94
0.80	0.18	27.59	0.00	0.00	0.00	0.28	1.00
0.90	0.22	27.74	0.00	0.00	0.01	0.38	1.00
1.00	0.26	27.88	0.00	0.00	0.09	0.48	1.00
1.10	0.32	28.03	0.00	0.00	0.18	0.58	1.00
1.20	0.36	28.19	0.00	0.00	0.26	0.68	1.00
1.30	0.41	28.33	0.00	0.00	0.34	0.78	1.00
1.40	0.46	28.48	0.00	0.00	0.43	0.88	1.00
1.50	0.51	28.64	0.00	0.04	0.52	0.99	1.00
1.60	0.55	28.78	0.00	0.11	0.60	1.00	1.00
1.70	0.59	28.94	0.00	0.18	0.69	1.00	1.00
1.80	0.63	29.08	0.00	0.23	0.77	1.00	1.00
1.90	0.66	29.24	0.00	0.30	0.86	1.00	1.00
2.00	0.69	29.39	0.00	0.36	0.94	1.00	1.00

Table 36: Put option prices for February Nino 3.4 SST conditioned on IRI ensemble forecasts released in December

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.62	24.83	0.14	0.47	0.62	0.78	1.00
-1.90	0.57	24.92	0.09	0.43	0.57	0.72	1.00
-1.80	0.53	25.00	0.05	0.38	0.53	0.67	1.00
-1.70	0.48	25.09	0.01	0.33	0.48	0.62	0.94
-1.60	0.43	25.18	0.00	0.28	0.43	0.57	0.89
-1.50	0.38	25.27	0.00	0.24	0.38	0.52	0.83
-1.40	0.33	25.36	0.00	0.19	0.32	0.46	0.78
-1.30	0.29	25.45	0.00	0.14	0.28	0.41	0.72
-1.20	0.24	25.54	0.00	0.09	0.22	0.36	0.66
-1.10	0.20	25.63	0.00	0.04	0.17	0.31	0.61
-1.00	0.16	25.72	0.00	0.00	0.12	0.26	0.55
-0.90	0.12	25.81	0.00	0.00	0.07	0.20	0.50
-0.80	0.09	25.90	0.00	0.00	0.02	0.15	0.45
-0.70	0.07	25.99	0.00	0.00	0.00	0.10	0.40
-0.60	0.05	26.07	0.00	0.00	0.00	0.05	0.34
-0.50	0.03	26.16	0.00	0.00	0.00	0.00	0.29
-0.40	0.02	26.25	0.00	0.00	0.00	0.00	0.24
-0.30	0.01	26.35	0.00	0.00	0.00	0.00	0.18
-0.20	0.01	26.43	0.00	0.00	0.00	0.00	0.13
-0.10	0.01	26.52	0.00	0.00	0.00	0.00	0.08
0.00	0.00	26.61	0.00	0.00	0.00	0.00	0.03
0.10	0.00	26.70	0.00	0.00	0.00	0.00	0.00
0.20	0.00	26.79	0.00	0.00	0.00	0.00	0.00
0.30	0.00	26.88	0.00	0.00	0.00	0.00	0.00
0.40	0.00	26.97	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.06	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.15	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.24	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.33	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.42	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.51	0.00	0.00	0.00	0.00	0.00
1.10	0.00	27.60	0.00	0.00	0.00	0.00	0.00
1.20	0.00	27.68	0.00	0.00	0.00	0.00	0.00
1.30	0.00	27.77	0.00	0.00	0.00	0.00	0.00
1.40	0.00	27.86	0.00	0.00	0.00	0.00	0.00
1.50	0.00	27.95	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.04	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.13	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.22	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.31	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.40	0.00	0.00	0.00	0.00	0.00

Table 37: Put option prices for February Nino 3.4 SST conditioned on IRI ensemble forecasts released in November

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.66	24.72	0.04	0.49	0.68	0.88	1.00
-1.90	0.62	24.81	0.00	0.44	0.63	0.83	1.00
-1.80	0.57	24.91	0.00	0.39	0.58	0.77	1.00
-1.70	0.53	25.00	0.00	0.34	0.53	0.72	1.00
-1.60	0.48	25.09	0.00	0.29	0.48	0.66	1.00
-1.50	0.43	25.18	0.00	0.24	0.43	0.61	1.00
-1.40	0.39	25.28	0.00	0.19	0.37	0.55	0.96
-1.30	0.34	25.37	0.00	0.14	0.32	0.50	0.90
-1.20	0.29	25.46	0.00	0.09	0.27	0.44	0.84
-1.10	0.25	25.55	0.00	0.04	0.22	0.39	0.79
-1.00	0.21	25.64	0.00	0.00	0.16	0.34	0.72
-0.90	0.17	25.73	0.00	0.00	0.12	0.29	0.67
-0.80	0.14	25.83	0.00	0.00	0.06	0.23	0.61
-0.70	0.11	25.92	0.00	0.00	0.01	0.18	0.55
-0.60	0.08	26.01	0.00	0.00	0.00	0.12	0.50
-0.50	0.06	26.11	0.00	0.00	0.00	0.07	0.44
-0.40	0.05	26.19	0.00	0.00	0.00	0.02	0.39
-0.30	0.03	26.29	0.00	0.00	0.00	0.00	0.33
-0.20	0.02	26.38	0.00	0.00	0.00	0.00	0.28
-0.10	0.02	26.48	0.00	0.00	0.00	0.00	0.22
0.00	0.01	26.57	0.00	0.00	0.00	0.00	0.17
0.10	0.01	26.66	0.00	0.00	0.00	0.00	0.12
0.20	0.01	26.75	0.00	0.00	0.00	0.00	0.07
0.30	0.00	26.84	0.00	0.00	0.00	0.00	0.02
0.40	0.00	26.93	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.03	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.12	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.21	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.30	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.39	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.49	0.00	0.00	0.00	0.00	0.00
1.10	0.00	27.58	0.00	0.00	0.00	0.00	0.00
1.20	0.00	27.67	0.00	0.00	0.00	0.00	0.00
1.30	0.00	27.76	0.00	0.00	0.00	0.00	0.00
1.40	0.00	27.85	0.00	0.00	0.00	0.00	0.00
1.50	0.00	27.94	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.04	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.13	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.22	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.32	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.41	0.00	0.00	0.00	0.00	0.00

Table 38: Put option prices for February Nino 3.4 SST conditioned on IRI ensemble forecasts released in October

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.72	24.54	0.00	0.54	0.78	1.00	1.00
-1.90	0.68	24.64	0.00	0.49	0.73	0.97	1.00
-1.80	0.64	24.74	0.00	0.44	0.67	0.91	1.00
-1.70	0.60	24.84	0.00	0.39	0.62	0.85	1.00
-1.60	0.55	24.94	0.00	0.33	0.56	0.79	1.00
-1.50	0.51	25.04	0.00	0.29	0.51	0.73	1.00
-1.40	0.46	25.14	0.00	0.23	0.45	0.66	1.00
-1.30	0.41	25.24	0.00	0.18	0.40	0.61	1.00
-1.20	0.36	25.34	0.00	0.13	0.34	0.55	1.00
-1.10	0.31	25.44	0.00	0.07	0.28	0.49	0.95
-1.00	0.27	25.53	0.00	0.02	0.23	0.44	0.90
-0.90	0.23	25.63	0.00	0.00	0.18	0.37	0.84
-0.80	0.19	25.73	0.00	0.00	0.12	0.32	0.77
-0.70	0.16	25.83	0.00	0.00	0.06	0.26	0.70
-0.60	0.12	25.92	0.00	0.00	0.01	0.20	0.64
-0.50	0.10	26.03	0.00	0.00	0.00	0.14	0.58
-0.40	0.07	26.13	0.00	0.00	0.00	0.09	0.52
-0.30	0.06	26.23	0.00	0.00	0.00	0.03	0.46
-0.20	0.04	26.32	0.00	0.00	0.00	0.00	0.40
-0.10	0.03	26.42	0.00	0.00	0.00	0.00	0.34
0.00	0.02	26.52	0.00	0.00	0.00	0.00	0.28
0.10	0.02	26.62	0.00	0.00	0.00	0.00	0.23
0.20	0.01	26.72	0.00	0.00	0.00	0.00	0.18
0.30	0.01	26.81	0.00	0.00	0.00	0.00	0.12
0.40	0.01	26.91	0.00	0.00	0.00	0.00	0.07
0.50	0.00	27.02	0.00	0.00	0.00	0.00	0.01
0.60	0.00	27.11	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.21	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.31	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.41	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.51	0.00	0.00	0.00	0.00	0.00
1.10	0.00	27.60	0.00	0.00	0.00	0.00	0.00
1.20	0.00	27.70	0.00	0.00	0.00	0.00	0.00
1.30	0.00	27.80	0.00	0.00	0.00	0.00	0.00
1.40	0.00	27.90	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.00	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.10	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.19	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.29	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.39	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.49	0.00	0.00	0.00	0.00	0.00

Table 39: Put option prices for February Nino 3.4 SST conditioned on IRI ensemble forecasts released in September

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.81	24.21	0.01	0.68	0.97	1.00	1.00
-1.90	0.78	24.32	0.00	0.62	0.91	1.00	1.00
-1.80	0.75	24.44	0.00	0.57	0.85	1.00	1.00
-1.70	0.71	24.55	0.00	0.50	0.78	1.00	1.00
-1.60	0.67	24.66	0.00	0.45	0.72	0.99	1.00
-1.50	0.62	24.77	0.00	0.40	0.66	0.92	1.00
-1.40	0.57	24.89	0.00	0.34	0.59	0.85	1.00
-1.30	0.53	25.00	0.00	0.28	0.53	0.79	1.00
-1.20	0.48	25.10	0.00	0.23	0.47	0.72	1.00
-1.10	0.43	25.21	0.00	0.17	0.41	0.65	1.00
-1.00	0.37	25.33	0.00	0.11	0.35	0.58	1.00
-0.90	0.32	25.44	0.00	0.05	0.28	0.51	1.00
-0.80	0.28	25.55	0.00	0.00	0.22	0.45	0.96
-0.70	0.23	25.66	0.00	0.00	0.16	0.38	0.88
-0.60	0.19	25.77	0.00	0.00	0.10	0.32	0.80
-0.50	0.15	25.89	0.00	0.00	0.03	0.25	0.74
-0.40	0.12	25.99	0.00	0.00	0.00	0.19	0.67
-0.30	0.09	26.10	0.00	0.00	0.00	0.12	0.61
-0.20	0.07	26.22	0.00	0.00	0.00	0.06	0.53
-0.10	0.05	26.33	0.00	0.00	0.00	0.00	0.46
0.00	0.04	26.44	0.00	0.00	0.00	0.00	0.39
0.10	0.03	26.55	0.00	0.00	0.00	0.00	0.33
0.20	0.02	26.66	0.00	0.00	0.00	0.00	0.26
0.30	0.01	26.78	0.00	0.00	0.00	0.00	0.21
0.40	0.01	26.88	0.00	0.00	0.00	0.00	0.14
0.50	0.01	27.00	0.00	0.00	0.00	0.00	0.10
0.60	0.01	27.10	0.00	0.00	0.00	0.00	0.04
0.70	0.00	27.21	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.32	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.43	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.55	0.00	0.00	0.00	0.00	0.00
1.10	0.00	27.66	0.00	0.00	0.00	0.00	0.00
1.20	0.00	27.77	0.00	0.00	0.00	0.00	0.00
1.30	0.00	27.88	0.00	0.00	0.00	0.00	0.00
1.40	0.00	27.99	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.10	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.21	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.33	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.43	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.55	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.66	0.00	0.00	0.00	0.00	0.00

Table 40: Put option prices for February Nino 3.4 SST conditioned on IRI ensemble forecasts released in August

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.88	23.86	0.14	0.85	1.00	1.00	1.00
-1.90	0.86	23.99	0.10	0.79	1.00	1.00	1.00
-1.80	0.83	24.11	0.04	0.73	1.00	1.00	1.00
-1.70	0.80	24.24	0.00	0.66	0.95	1.00	1.00
-1.60	0.76	24.37	0.00	0.60	0.88	1.00	1.00
-1.50	0.73	24.49	0.00	0.53	0.81	1.00	1.00
-1.40	0.68	24.62	0.00	0.47	0.74	1.00	1.00
-1.30	0.63	24.74	0.00	0.41	0.67	0.94	1.00
-1.20	0.58	24.87	0.00	0.34	0.60	0.86	1.00
-1.10	0.52	25.00	0.00	0.28	0.53	0.78	1.00
-1.00	0.47	25.12	0.00	0.22	0.46	0.71	1.00
-0.90	0.41	25.25	0.00	0.15	0.39	0.63	1.00
-0.80	0.35	25.37	0.00	0.08	0.32	0.55	1.00
-0.70	0.29	25.51	0.00	0.01	0.25	0.48	0.98
-0.60	0.25	25.62	0.00	0.00	0.18	0.41	0.91
-0.50	0.20	25.75	0.00	0.00	0.11	0.33	0.82
-0.40	0.15	25.88	0.00	0.00	0.03	0.25	0.74
-0.30	0.12	26.00	0.00	0.00	0.00	0.18	0.68
-0.20	0.09	26.13	0.00	0.00	0.00	0.11	0.58
-0.10	0.06	26.26	0.00	0.00	0.00	0.04	0.51
0.00	0.04	26.38	0.00	0.00	0.00	0.00	0.43
0.10	0.03	26.51	0.00	0.00	0.00	0.00	0.36
0.20	0.02	26.64	0.00	0.00	0.00	0.00	0.29
0.30	0.02	26.76	0.00	0.00	0.00	0.00	0.22
0.40	0.01	26.89	0.00	0.00	0.00	0.00	0.15
0.50	0.01	27.02	0.00	0.00	0.00	0.00	0.08
0.60	0.01	27.14	0.00	0.00	0.00	0.00	0.03
0.70	0.00	27.26	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.39	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.52	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.65	0.00	0.00	0.00	0.00	0.00
1.10	0.00	27.77	0.00	0.00	0.00	0.00	0.00
1.20	0.00	27.90	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.02	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.15	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.27	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.40	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.52	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.65	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.78	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.90	0.00	0.00	0.00	0.00	0.00

Table 41: Put option prices for February Nino 3.4 SST conditioned on IRI ensemble forecasts released in July

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.91	23.40	0.11	1.00	1.00	1.00	1.00
-1.90	0.90	23.55	0.06	0.97	1.00	1.00	1.00
-1.80	0.88	23.69	0.02	0.89	1.00	1.00	1.00
-1.70	0.86	23.85	0.00	0.82	1.00	1.00	1.00
-1.60	0.84	23.99	0.00	0.76	1.00	1.00	1.00
-1.50	0.80	24.14	0.00	0.67	1.00	1.00	1.00
-1.40	0.77	24.29	0.00	0.61	0.93	1.00	1.00
-1.30	0.73	24.44	0.00	0.53	0.85	1.00	1.00
-1.20	0.68	24.59	0.00	0.46	0.76	1.00	1.00
-1.10	0.63	24.74	0.00	0.38	0.68	0.97	1.00
-1.00	0.57	24.89	0.00	0.31	0.59	0.88	1.00
-0.90	0.51	25.04	0.00	0.23	0.51	0.79	1.00
-0.80	0.44	25.19	0.00	0.16	0.43	0.69	1.00
-0.70	0.38	25.34	0.00	0.08	0.34	0.60	1.00
-0.60	0.32	25.48	0.00	0.00	0.26	0.52	1.00
-0.50	0.25	25.64	0.00	0.00	0.17	0.42	1.00
-0.40	0.20	25.79	0.00	0.00	0.08	0.34	0.89
-0.30	0.15	25.93	0.00	0.00	0.01	0.25	0.80
-0.20	0.11	26.08	0.00	0.00	0.00	0.16	0.70
-0.10	0.08	26.24	0.00	0.00	0.00	0.07	0.60
0.00	0.06	26.38	0.00	0.00	0.00	0.00	0.52
0.10	0.04	26.53	0.00	0.00	0.00	0.00	0.44
0.20	0.03	26.68	0.00	0.00	0.00	0.00	0.35
0.30	0.02	26.83	0.00	0.00	0.00	0.00	0.27
0.40	0.01	26.98	0.00	0.00	0.00	0.00	0.19
0.50	0.01	27.13	0.00	0.00	0.00	0.00	0.13
0.60	0.01	27.28	0.00	0.00	0.00	0.00	0.05
0.70	0.01	27.43	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.58	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.73	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.88	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.04	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.18	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.32	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.47	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.63	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.78	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.92	0.00	0.00	0.00	0.00	0.00
1.80	0.00	29.07	0.00	0.00	0.00	0.00	0.00
1.90	0.00	29.22	0.00	0.00	0.00	0.00	0.00
2.00	0.00	29.37	0.00	0.00	0.00	0.00	0.00

Table 42: Put option prices for February Nino 3.4 SST conditioned on IRI ensemble forecasts released in June

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.90	23.39	0.00	0.99	1.00	1.00	1.00
-1.90	0.88	23.54	0.00	0.93	1.00	1.00	1.00
-1.80	0.86	23.70	0.00	0.85	1.00	1.00	1.00
-1.70	0.84	23.85	0.00	0.78	1.00	1.00	1.00
-1.60	0.82	24.00	0.00	0.71	1.00	1.00	1.00
-1.50	0.79	24.15	0.00	0.63	1.00	1.00	1.00
-1.40	0.75	24.30	0.00	0.56	0.92	1.00	1.00
-1.30	0.71	24.46	0.00	0.49	0.83	1.00	1.00
-1.20	0.66	24.61	0.00	0.41	0.74	1.00	1.00
-1.10	0.61	24.77	0.00	0.34	0.66	0.98	1.00
-1.00	0.55	24.92	0.00	0.26	0.57	0.88	1.00
-0.90	0.49	25.07	0.00	0.19	0.49	0.79	1.00
-0.80	0.43	25.22	0.00	0.11	0.40	0.70	1.00
-0.70	0.36	25.38	0.00	0.03	0.32	0.60	1.00
-0.60	0.30	25.53	0.00	0.00	0.23	0.51	1.00
-0.50	0.25	25.68	0.00	0.00	0.15	0.42	1.00
-0.40	0.19	25.84	0.00	0.00	0.05	0.32	0.92
-0.30	0.15	25.99	0.00	0.00	0.00	0.23	0.82
-0.20	0.11	26.14	0.00	0.00	0.00	0.14	0.71
-0.10	0.08	26.29	0.00	0.00	0.00	0.05	0.62
0.00	0.05	26.45	0.00	0.00	0.00	0.00	0.51
0.10	0.04	26.60	0.00	0.00	0.00	0.00	0.43
0.20	0.03	26.75	0.00	0.00	0.00	0.00	0.35
0.30	0.02	26.90	0.00	0.00	0.00	0.00	0.28
0.40	0.01	27.06	0.00	0.00	0.00	0.00	0.20
0.50	0.01	27.21	0.00	0.00	0.00	0.00	0.12
0.60	0.01	27.36	0.00	0.00	0.00	0.00	0.04
0.70	0.01	27.52	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.67	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.82	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.98	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.13	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.28	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.43	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.58	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.74	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.90	0.00	0.00	0.00	0.00	0.00
1.70	0.00	29.04	0.00	0.00	0.00	0.00	0.00
1.80	0.00	29.20	0.00	0.00	0.00	0.00	0.00
1.90	0.00	29.35	0.00	0.00	0.00	0.00	0.00
2.00	0.00	29.50	0.00	0.00	0.00	0.00	0.00

Table 43: Put option prices for February Nino 3.4 SST conditioned on IRI ensemble forecasts released in May

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.88	23.14	0.00	1.00	1.00	1.00	1.00
-1.90	0.87	23.30	0.00	0.94	1.00	1.00	1.00
-1.80	0.85	23.47	0.00	0.87	1.00	1.00	1.00
-1.70	0.83	23.63	0.00	0.79	1.00	1.00	1.00
-1.60	0.81	23.80	0.00	0.72	1.00	1.00	1.00
-1.50	0.79	23.97	0.00	0.64	1.00	1.00	1.00
-1.40	0.76	24.13	0.00	0.57	1.00	1.00	1.00
-1.30	0.72	24.30	0.00	0.49	0.92	1.00	1.00
-1.20	0.69	24.46	0.00	0.42	0.83	1.00	1.00
-1.10	0.64	24.64	0.00	0.34	0.73	1.00	1.00
-1.00	0.59	24.80	0.00	0.26	0.64	1.00	1.00
-0.90	0.53	24.97	0.00	0.18	0.55	0.91	1.00
-0.80	0.47	25.13	0.00	0.11	0.46	0.81	1.00
-0.70	0.41	25.30	0.00	0.02	0.36	0.70	1.00
-0.60	0.35	25.47	0.00	0.00	0.27	0.60	1.00
-0.50	0.28	25.63	0.00	0.00	0.17	0.49	1.00
-0.40	0.22	25.80	0.00	0.00	0.08	0.39	1.00
-0.30	0.18	25.96	0.00	0.00	0.00	0.29	0.96
-0.20	0.13	26.13	0.00	0.00	0.00	0.19	0.84
-0.10	0.09	26.30	0.00	0.00	0.00	0.08	0.72
0.00	0.07	26.46	0.00	0.00	0.00	0.00	0.62
0.10	0.05	26.63	0.00	0.00	0.00	0.00	0.52
0.20	0.03	26.79	0.00	0.00	0.00	0.00	0.44
0.30	0.02	26.96	0.00	0.00	0.00	0.00	0.36
0.40	0.02	27.13	0.00	0.00	0.00	0.00	0.28
0.50	0.01	27.29	0.00	0.00	0.00	0.00	0.21
0.60	0.01	27.45	0.00	0.00	0.00	0.00	0.14
0.70	0.01	27.63	0.00	0.00	0.00	0.00	0.07
0.80	0.01	27.79	0.00	0.00	0.00	0.00	0.02
0.90	0.01	27.95	0.00	0.00	0.00	0.00	0.00
1.00	0.01	28.12	0.00	0.00	0.00	0.00	0.00
1.10	0.01	28.28	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.46	0.00	0.00	0.00	0.00	0.00
1.30	0.01	28.62	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.78	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.96	0.00	0.00	0.00	0.00	0.00
1.60	0.00	29.12	0.00	0.00	0.00	0.00	0.00
1.70	0.00	29.28	0.00	0.00	0.00	0.00	0.00
1.80	0.00	29.45	0.00	0.00	0.00	0.00	0.00
1.90	0.00	29.61	0.00	0.00	0.00	0.00	0.00
2.00	0.00	29.78	0.00	0.00	0.00	0.00	0.00

Table 44: Put option prices for February Nino 3.4 SST conditioned on IRI ensemble forecasts released in April

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.82	23.38	0.00	0.79	1.00	1.00	1.00
-1.90	0.81	23.52	0.00	0.73	1.00	1.00	1.00
-1.80	0.79	23.68	0.00	0.67	1.00	1.00	1.00
-1.70	0.77	23.83	0.00	0.61	1.00	1.00	1.00
-1.60	0.75	23.97	0.00	0.55	1.00	1.00	1.00
-1.50	0.73	24.12	0.00	0.48	1.00	1.00	1.00
-1.40	0.70	24.28	0.00	0.42	0.94	1.00	1.00
-1.30	0.67	24.42	0.00	0.35	0.85	1.00	1.00
-1.20	0.64	24.58	0.00	0.29	0.77	1.00	1.00
-1.10	0.60	24.72	0.00	0.23	0.69	1.00	1.00
-1.00	0.55	24.88	0.00	0.16	0.60	1.00	1.00
-0.90	0.51	25.02	0.00	0.09	0.52	0.94	1.00
-0.80	0.46	25.18	0.00	0.03	0.43	0.83	1.00
-0.70	0.41	25.33	0.00	0.00	0.35	0.73	1.00
-0.60	0.35	25.48	0.00	0.00	0.26	0.63	1.00
-0.50	0.30	25.64	0.00	0.00	0.17	0.53	1.00
-0.40	0.25	25.79	0.00	0.00	0.09	0.43	1.00
-0.30	0.20	25.94	0.00	0.00	0.00	0.34	1.00
-0.20	0.16	26.08	0.00	0.00	0.00	0.25	0.99
-0.10	0.12	26.23	0.00	0.00	0.00	0.16	0.88
0.00	0.09	26.38	0.00	0.00	0.00	0.07	0.77
0.10	0.07	26.53	0.00	0.00	0.00	0.00	0.68
0.20	0.05	26.68	0.00	0.00	0.00	0.00	0.59
0.30	0.04	26.84	0.00	0.00	0.00	0.00	0.51
0.40	0.03	26.98	0.00	0.00	0.00	0.00	0.46
0.50	0.03	27.14	0.00	0.00	0.00	0.00	0.38
0.60	0.02	27.28	0.00	0.00	0.00	0.00	0.32
0.70	0.02	27.44	0.00	0.00	0.00	0.00	0.27
0.80	0.02	27.59	0.00	0.00	0.00	0.00	0.23
0.90	0.01	27.74	0.00	0.00	0.00	0.00	0.18
1.00	0.01	27.88	0.00	0.00	0.00	0.00	0.14
1.10	0.01	28.03	0.00	0.00	0.00	0.00	0.13
1.20	0.01	28.19	0.00	0.00	0.00	0.00	0.10
1.30	0.01	28.33	0.00	0.00	0.00	0.00	0.07
1.40	0.01	28.48	0.00	0.00	0.00	0.00	0.05
1.50	0.01	28.64	0.00	0.00	0.00	0.00	0.04
1.60	0.01	28.78	0.00	0.00	0.00	0.00	0.02
1.70	0.01	28.94	0.00	0.00	0.00	0.00	0.00
1.80	0.01	29.08	0.00	0.00	0.00	0.00	0.00
1.90	0.01	29.24	0.00	0.00	0.00	0.00	0.00
2.00	0.01	29.39	0.00	0.00	0.00	0.00	0.00

Appendix F: March Pricing

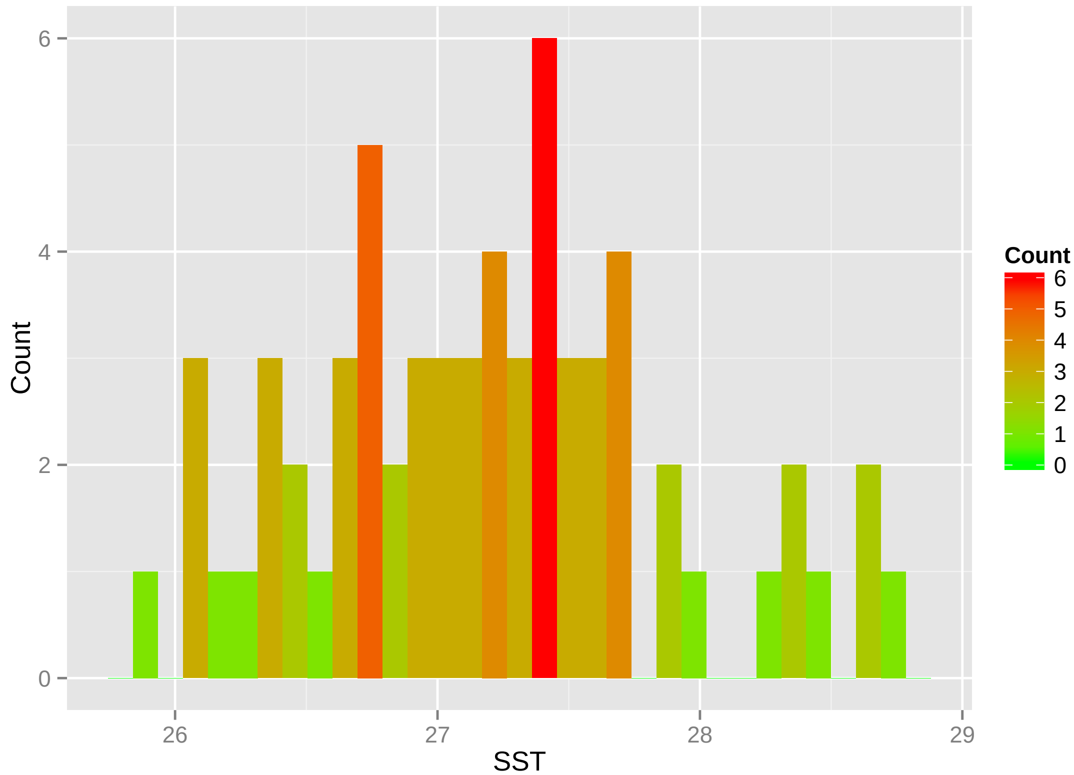


Figure 39: Histogram of March SST for Niño 3.4 ERSST.3b

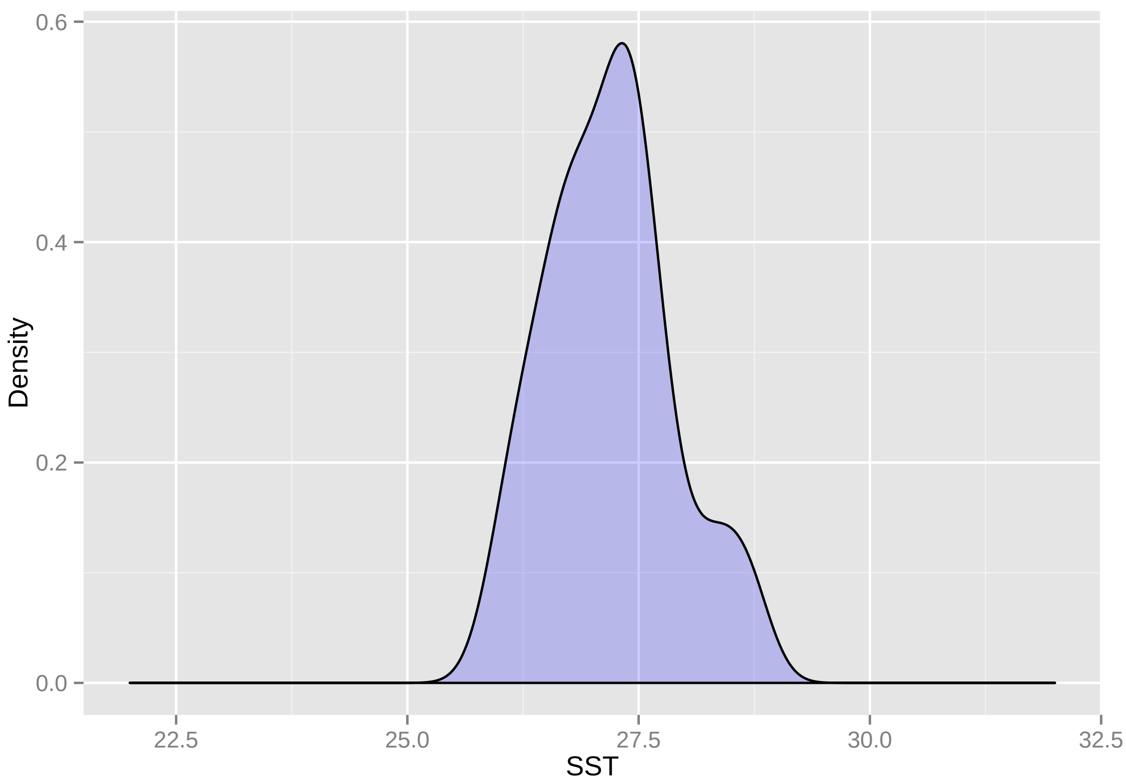


Figure 40: Kernel density estimate of March SST for Niño 3.4 ERSST.3b

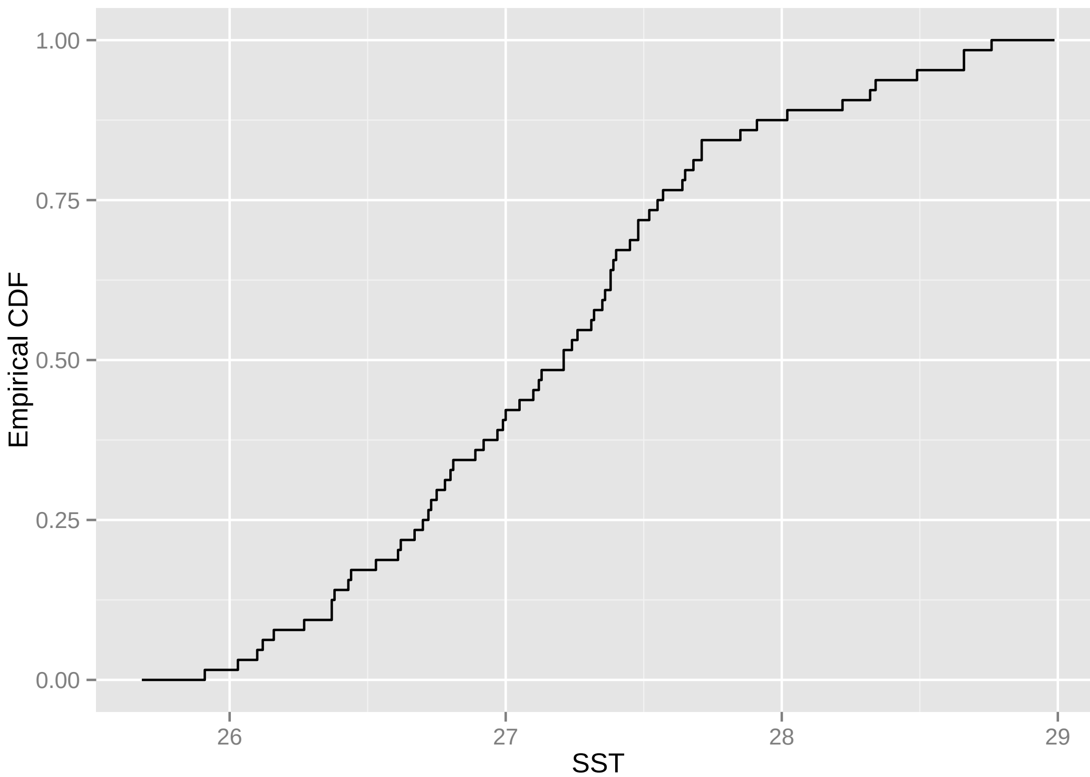


Figure 41: ECDF of March SST for Niño 3.4 ERSST.3b

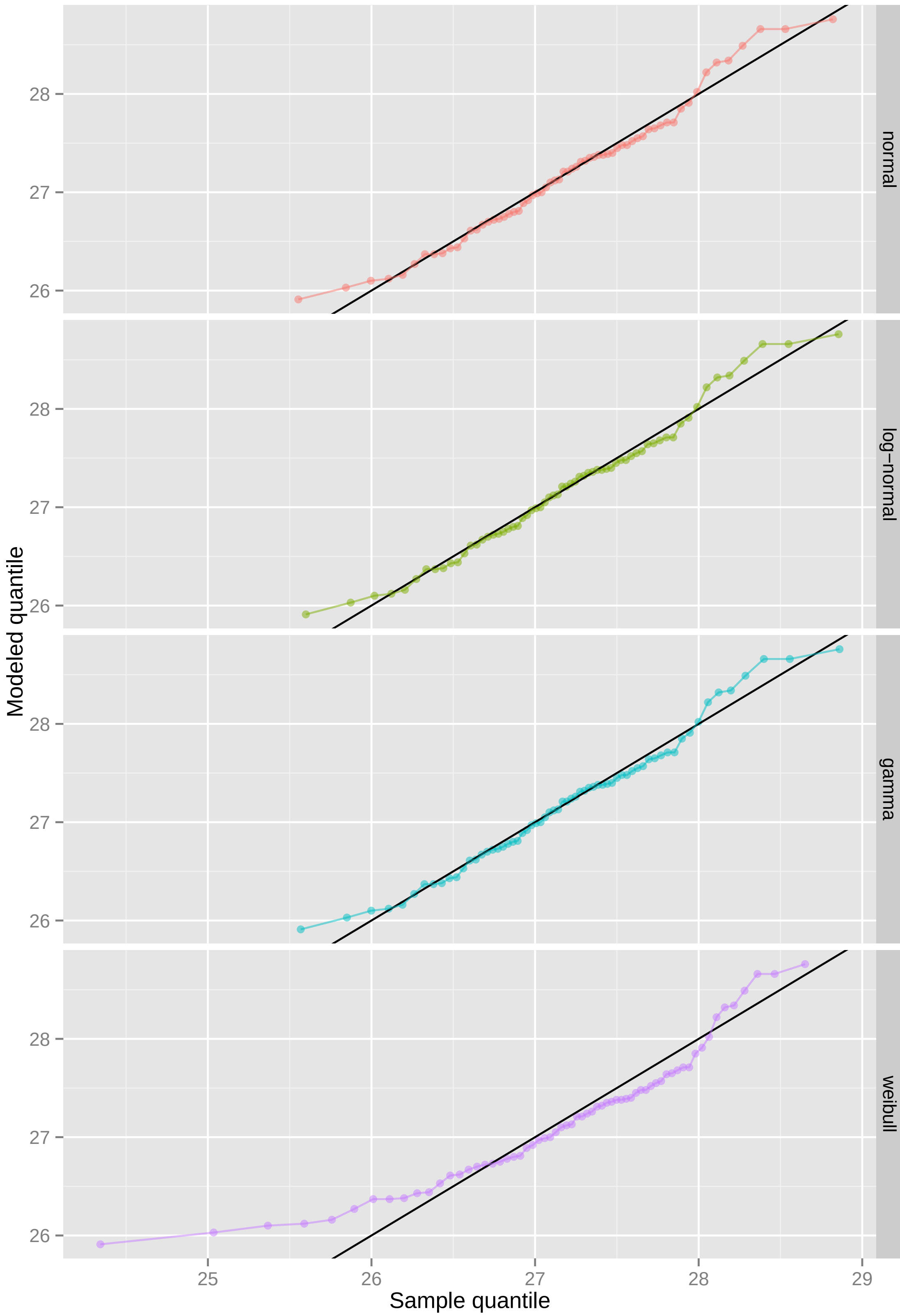


Figure 42: QQ plots of March SST for Niño 3.4 ERSST.3b compared to samples from various distributions (n=2 million)

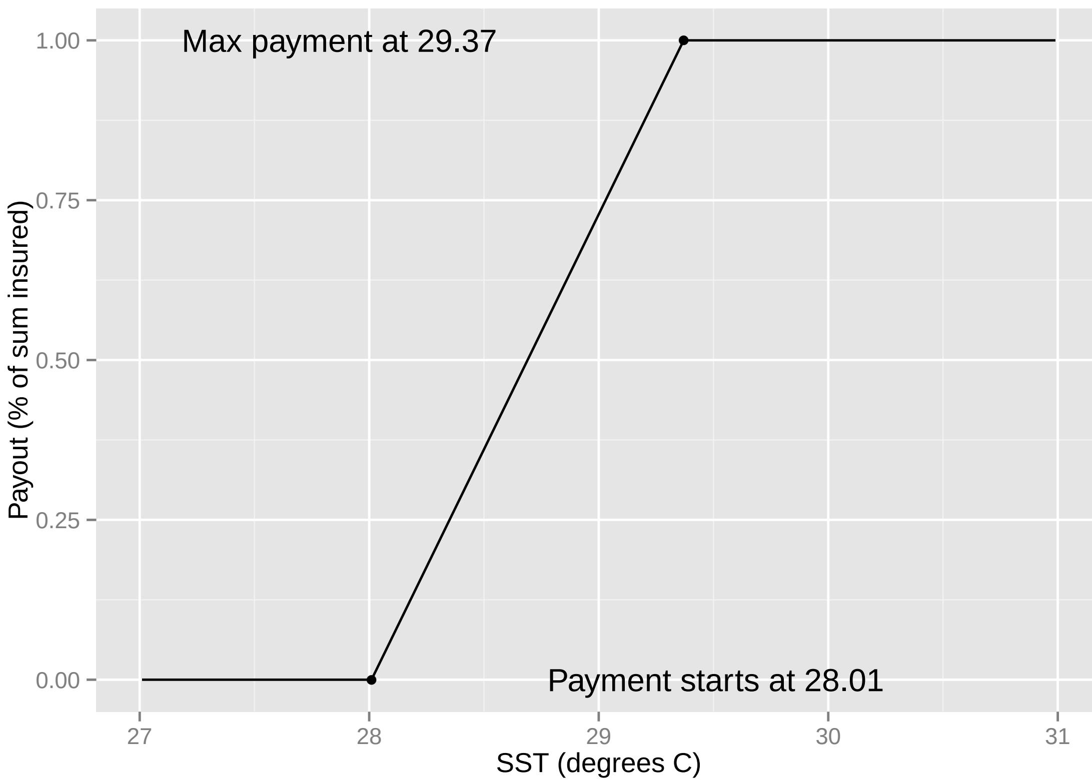


Figure 43: Payout function for call option on March SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations above the baseline

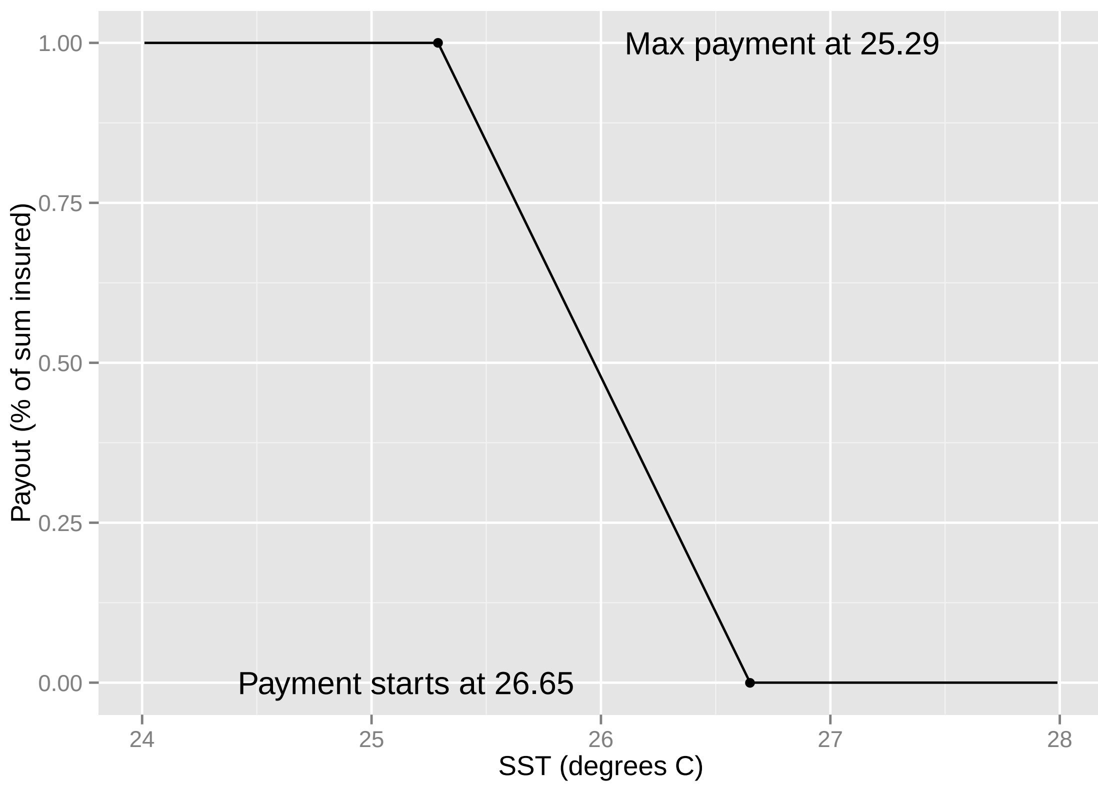


Figure 44: Payout function for put option on March SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

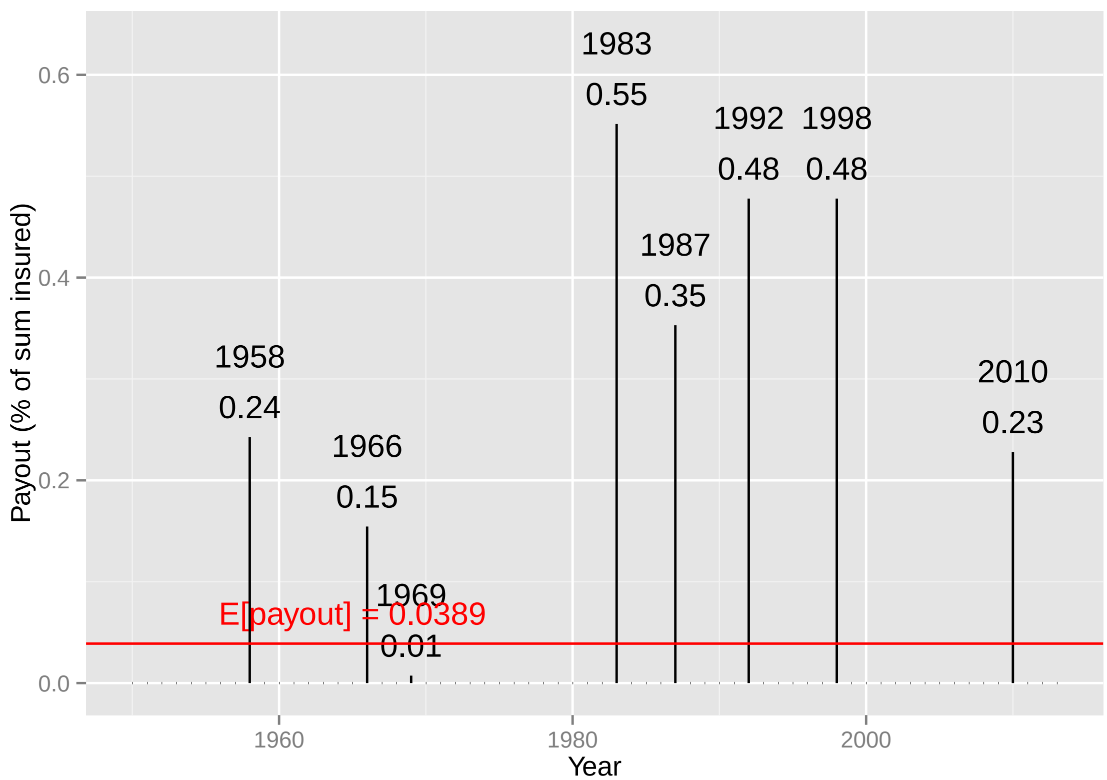


Figure 45: Historical burn on call option for March SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations above the baseline

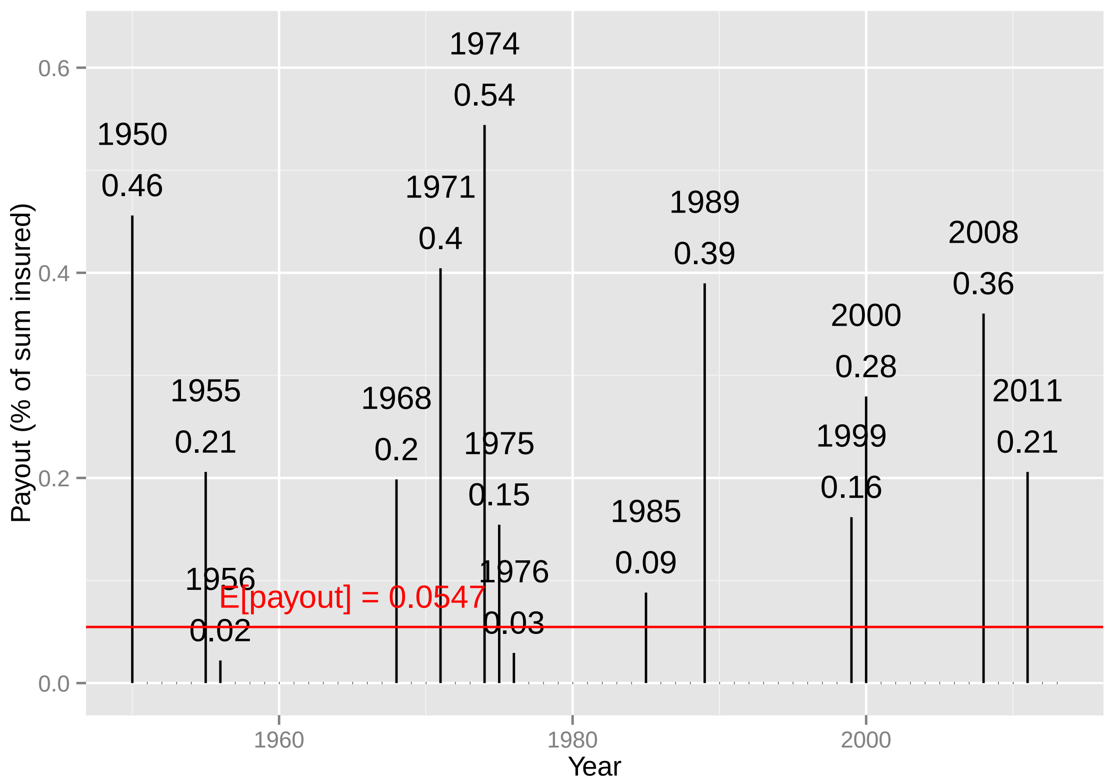


Figure 46: Historical burn on put option on March SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

Table 45: Bayesian regression linking March Niño 3.4 SST anomalies to average of relevant IRI ensemble forecasts

	mean	sd	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q	n_eff	Rhat
January forecast average covering March Niño 3.4 SST anomalies									
α	-0.10	0.10	-0.30	-0.20	-0.10	-0.10	0.00	98140	1
β	0.80	0.10	0.60	0.70	0.80	0.80	1.00	96008	1
σ_y^2	0.10	0.00	0.00	0.00	0.10	0.10	0.20	56035	1
December forecast average covering March Niño 3.4 SST anomalies									
α	-0.20	0.10	-0.40	-0.30	-0.20	-0.10	0.00	97569	1
β	0.80	0.10	0.50	0.70	0.80	0.80	1.00	92532	1
σ_y^2	0.10	0.10	0.00	0.10	0.10	0.10	0.30	54402	1
November forecast average covering March Niño 3.4 SST anomalies									
α	-0.20	0.10	-0.50	-0.30	-0.20	-0.20	0.00	97324	1
β	0.80	0.20	0.50	0.70	0.80	0.90	1.10	95654	1
σ_y^2	0.10	0.10	0.00	0.10	0.10	0.20	0.40	54234	1
October forecast average covering March Niño 3.4 SST anomalies									
α	-0.30	0.10	-0.50	-0.40	-0.30	-0.20	0.00	94448	1
β	0.80	0.20	0.40	0.70	0.80	1.00	1.20	93064	1
σ_y^2	0.20	0.10	0.10	0.10	0.10	0.20	0.40	55365	1
September forecast average covering March Niño 3.4 SST anomalies									
α	-0.30	0.10	-0.60	-0.40	-0.30	-0.30	-0.10	92708	1
β	1.00	0.20	0.50	0.80	1.00	1.10	1.50	86385	1
σ_y^2	0.20	0.10	0.10	0.10	0.10	0.20	0.50	55035	1
August forecast average covering March Niño 3.4 SST anomalies									
α	-0.40	0.10	-0.60	-0.50	-0.40	-0.30	-0.10	87529	1
β	1.10	0.30	0.60	0.90	1.10	1.30	1.60	86183	1
σ_y^2	0.20	0.10	0.10	0.10	0.10	0.20	0.50	53365	1
July forecast average covering March Niño 3.4 SST anomalies									
α	-0.40	0.20	-0.70	-0.50	-0.40	-0.30	-0.10	86421	1
β	1.30	0.40	0.60	1.10	1.30	1.50	2.10	83829	1
σ_y^2	0.20	0.20	0.10	0.10	0.20	0.30	0.60	53831	1
June forecast average covering March Niño 3.4 SST anomalies									
α	-0.30	0.20	-0.60	-0.40	-0.30	-0.20	0.00	87648	1
β	1.20	0.40	0.40	1.00	1.20	1.40	2.00	85076	1
σ_y^2	0.30	0.20	0.10	0.20	0.20	0.30	0.70	55629	1
May forecast average covering March Niño 3.4 SST anomalies									
α	-0.30	0.20	-0.70	-0.40	-0.30	-0.20	0.00	92536	1
β	1.30	0.50	0.30	1.00	1.30	1.60	2.30	87503	1
σ_y^2	0.30	0.20	0.10	0.20	0.30	0.40	0.80	55517	1

Table 46: Call option prices for March Nino 3.4 SST conditioned on IRI ensemble forecasts released in January

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	25.66	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	25.73	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	25.81	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	25.89	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	25.96	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	26.04	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	26.12	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	26.19	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	26.27	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	26.35	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	26.42	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	26.50	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	26.58	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	26.65	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	26.73	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	26.80	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.88	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.96	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	27.03	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	27.11	0.00	0.00	0.00	0.00	0.00
0.00	0.00	27.19	0.00	0.00	0.00	0.00	0.00
0.10	0.00	27.26	0.00	0.00	0.00	0.00	0.00
0.20	0.00	27.34	0.00	0.00	0.00	0.00	0.00
0.30	0.00	27.42	0.00	0.00	0.00	0.00	0.00
0.40	0.00	27.49	0.00	0.00	0.00	0.00	0.02
0.50	0.01	27.57	0.00	0.00	0.00	0.00	0.08
0.60	0.01	27.65	0.00	0.00	0.00	0.00	0.13
0.70	0.02	27.73	0.00	0.00	0.00	0.00	0.19
0.80	0.03	27.80	0.00	0.00	0.00	0.00	0.25
0.90	0.04	27.88	0.00	0.00	0.00	0.03	0.31
1.00	0.06	27.95	0.00	0.00	0.00	0.09	0.38
1.10	0.09	28.03	0.00	0.00	0.01	0.14	0.44
1.20	0.12	28.11	0.00	0.00	0.07	0.20	0.50
1.30	0.16	28.18	0.00	0.00	0.13	0.26	0.56
1.40	0.21	28.26	0.00	0.05	0.18	0.32	0.63
1.50	0.25	28.33	0.00	0.10	0.24	0.38	0.69
1.60	0.31	28.41	0.00	0.15	0.29	0.44	0.75
1.70	0.36	28.49	0.00	0.21	0.35	0.49	0.82
1.80	0.41	28.56	0.00	0.26	0.41	0.55	0.88
1.90	0.47	28.64	0.00	0.32	0.47	0.61	0.95
2.00	0.52	28.72	0.03	0.37	0.52	0.67	1.00

Table 47: Call option prices for March Nino 3.4 SST conditioned on IRI ensemble forecasts released in December

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	25.63	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	25.70	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	25.78	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	25.85	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	25.93	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	26.00	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	26.08	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	26.16	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	26.23	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	26.31	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	26.38	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	26.45	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	26.53	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	26.61	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	26.68	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	26.75	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.83	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.90	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.98	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	27.05	0.00	0.00	0.00	0.00	0.00
0.00	0.00	27.13	0.00	0.00	0.00	0.00	0.00
0.10	0.00	27.20	0.00	0.00	0.00	0.00	0.00
0.20	0.00	27.28	0.00	0.00	0.00	0.00	0.00
0.30	0.00	27.36	0.00	0.00	0.00	0.00	0.00
0.40	0.00	27.43	0.00	0.00	0.00	0.00	0.04
0.50	0.01	27.51	0.00	0.00	0.00	0.00	0.11
0.60	0.01	27.58	0.00	0.00	0.00	0.00	0.17
0.70	0.02	27.66	0.00	0.00	0.00	0.00	0.23
0.80	0.03	27.73	0.00	0.00	0.00	0.00	0.28
0.90	0.04	27.80	0.00	0.00	0.00	0.00	0.35
1.00	0.06	27.88	0.00	0.00	0.00	0.06	0.41
1.10	0.08	27.96	0.00	0.00	0.00	0.12	0.47
1.20	0.11	28.03	0.00	0.00	0.02	0.18	0.53
1.30	0.14	28.11	0.00	0.00	0.07	0.23	0.60
1.40	0.18	28.18	0.00	0.00	0.13	0.29	0.66
1.50	0.22	28.26	0.00	0.01	0.18	0.35	0.72
1.60	0.26	28.33	0.00	0.07	0.24	0.41	0.79
1.70	0.31	28.41	0.00	0.12	0.29	0.46	0.85
1.80	0.36	28.48	0.00	0.17	0.35	0.52	0.92
1.90	0.41	28.56	0.00	0.22	0.40	0.58	0.99
2.00	0.46	28.63	0.00	0.28	0.46	0.64	1.00

Table 48: Call option prices for March Nino 3.4 SST conditioned on IRI ensemble forecasts released in November

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	25.53	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	25.60	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	25.68	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	25.76	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	25.83	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	25.91	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	26.00	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	26.07	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	26.15	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	26.23	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	26.31	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	26.38	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	26.46	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	26.54	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	26.62	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	26.69	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.77	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.85	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.93	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	27.01	0.00	0.00	0.00	0.00	0.00
0.00	0.00	27.08	0.00	0.00	0.00	0.00	0.00
0.10	0.00	27.16	0.00	0.00	0.00	0.00	0.00
0.20	0.00	27.24	0.00	0.00	0.00	0.00	0.00
0.30	0.01	27.32	0.00	0.00	0.00	0.00	0.05
0.40	0.01	27.39	0.00	0.00	0.00	0.00	0.11
0.50	0.01	27.47	0.00	0.00	0.00	0.00	0.16
0.60	0.02	27.55	0.00	0.00	0.00	0.00	0.23
0.70	0.02	27.63	0.00	0.00	0.00	0.00	0.29
0.80	0.04	27.71	0.00	0.00	0.00	0.00	0.36
0.90	0.05	27.78	0.00	0.00	0.00	0.01	0.42
1.00	0.07	27.86	0.00	0.00	0.00	0.07	0.48
1.10	0.09	27.94	0.00	0.00	0.00	0.13	0.56
1.20	0.12	28.02	0.00	0.00	0.01	0.20	0.62
1.30	0.15	28.10	0.00	0.00	0.06	0.25	0.69
1.40	0.19	28.17	0.00	0.00	0.12	0.31	0.74
1.50	0.23	28.25	0.00	0.00	0.18	0.37	0.82
1.60	0.28	28.33	0.00	0.03	0.23	0.43	0.89
1.70	0.32	28.41	0.00	0.09	0.29	0.50	0.96
1.80	0.37	28.48	0.00	0.14	0.35	0.56	1.00
1.90	0.42	28.56	0.00	0.19	0.40	0.62	1.00
2.00	0.47	28.64	0.00	0.25	0.47	0.68	1.00

Table 49: Call option prices for March Nino 3.4 SST conditioned on IRI ensemble forecasts released in October

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	25.39	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	25.48	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	25.56	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	25.64	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	25.72	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	25.80	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	25.89	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	25.97	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	26.06	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	26.14	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	26.22	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	26.31	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	26.39	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	26.47	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	26.55	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	26.64	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.72	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.81	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.89	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	26.98	0.00	0.00	0.00	0.00	0.00
0.00	0.00	27.05	0.00	0.00	0.00	0.00	0.00
0.10	0.00	27.14	0.00	0.00	0.00	0.00	0.00
0.20	0.01	27.22	0.00	0.00	0.00	0.00	0.04
0.30	0.01	27.31	0.00	0.00	0.00	0.00	0.11
0.40	0.01	27.39	0.00	0.00	0.00	0.00	0.18
0.50	0.02	27.48	0.00	0.00	0.00	0.00	0.24
0.60	0.02	27.56	0.00	0.00	0.00	0.00	0.31
0.70	0.03	27.64	0.00	0.00	0.00	0.00	0.38
0.80	0.05	27.72	0.00	0.00	0.00	0.00	0.44
0.90	0.07	27.81	0.00	0.00	0.00	0.05	0.52
1.00	0.09	27.89	0.00	0.00	0.00	0.12	0.58
1.10	0.12	27.98	0.00	0.00	0.00	0.18	0.65
1.20	0.15	28.06	0.00	0.00	0.04	0.25	0.74
1.30	0.19	28.14	0.00	0.00	0.10	0.31	0.81
1.40	0.23	28.23	0.00	0.00	0.16	0.38	0.88
1.50	0.28	28.31	0.00	0.00	0.22	0.44	0.96
1.60	0.32	28.39	0.00	0.05	0.28	0.51	1.00
1.70	0.37	28.48	0.00	0.11	0.34	0.58	1.00
1.80	0.42	28.56	0.00	0.16	0.40	0.64	1.00
1.90	0.47	28.64	0.00	0.22	0.46	0.71	1.00
2.00	0.52	28.73	0.00	0.28	0.53	0.77	1.00

Table 50: Call option prices for March Nino 3.4 SST conditioned on IRI ensemble forecasts released in September

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	25.04	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	25.13	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	25.23	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	25.33	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	25.43	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	25.53	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	25.62	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	25.72	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	25.82	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.92	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	26.01	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	26.11	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	26.21	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	26.31	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	26.40	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	26.50	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.60	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.70	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.79	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	26.89	0.00	0.00	0.00	0.00	0.00
0.00	0.00	26.99	0.00	0.00	0.00	0.00	0.00
0.10	0.00	27.08	0.00	0.00	0.00	0.00	0.00
0.20	0.01	27.19	0.00	0.00	0.00	0.00	0.06
0.30	0.01	27.28	0.00	0.00	0.00	0.00	0.12
0.40	0.01	27.38	0.00	0.00	0.00	0.00	0.19
0.50	0.02	27.48	0.00	0.00	0.00	0.00	0.28
0.60	0.03	27.57	0.00	0.00	0.00	0.00	0.36
0.70	0.04	27.67	0.00	0.00	0.00	0.00	0.43
0.80	0.06	27.77	0.00	0.00	0.00	0.04	0.52
0.90	0.09	27.87	0.00	0.00	0.00	0.11	0.61
1.00	0.12	27.97	0.00	0.00	0.00	0.19	0.69
1.10	0.16	28.06	0.00	0.00	0.04	0.27	0.77
1.20	0.21	28.16	0.00	0.00	0.11	0.34	0.88
1.30	0.25	28.26	0.00	0.00	0.18	0.42	0.96
1.40	0.31	28.36	0.00	0.01	0.25	0.50	1.00
1.50	0.36	28.45	0.00	0.08	0.33	0.57	1.00
1.60	0.42	28.55	0.00	0.14	0.40	0.65	1.00
1.70	0.48	28.65	0.00	0.21	0.47	0.73	1.00
1.80	0.53	28.75	0.00	0.27	0.54	0.82	1.00
1.90	0.59	28.85	0.00	0.34	0.61	0.89	1.00
2.00	0.64	28.94	0.00	0.40	0.69	0.97	1.00

Table 51: Call option prices for March Nino 3.4 SST conditioned on IRI ensemble forecasts released in August

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	24.75	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	24.86	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.97	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	25.08	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	25.19	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	25.30	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	25.41	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	25.52	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	25.63	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.74	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.85	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.96	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	26.07	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	26.18	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	26.29	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	26.40	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.51	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.62	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.73	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	26.84	0.00	0.00	0.00	0.00	0.00
0.00	0.00	26.95	0.00	0.00	0.00	0.00	0.00
0.10	0.00	27.06	0.00	0.00	0.00	0.00	0.00
0.20	0.00	27.17	0.00	0.00	0.00	0.00	0.01
0.30	0.01	27.28	0.00	0.00	0.00	0.00	0.10
0.40	0.01	27.39	0.00	0.00	0.00	0.00	0.18
0.50	0.02	27.50	0.00	0.00	0.00	0.00	0.27
0.60	0.03	27.61	0.00	0.00	0.00	0.00	0.36
0.70	0.05	27.72	0.00	0.00	0.00	0.00	0.44
0.80	0.07	27.83	0.00	0.00	0.00	0.08	0.55
0.90	0.11	27.94	0.00	0.00	0.00	0.16	0.63
1.00	0.15	28.05	0.00	0.00	0.03	0.25	0.74
1.10	0.20	28.16	0.00	0.00	0.11	0.33	0.83
1.20	0.26	28.27	0.00	0.00	0.19	0.42	0.93
1.30	0.32	28.38	0.00	0.04	0.27	0.50	1.00
1.40	0.38	28.49	0.00	0.12	0.36	0.60	1.00
1.50	0.45	28.60	0.00	0.19	0.44	0.68	1.00
1.60	0.51	28.71	0.00	0.26	0.52	0.77	1.00
1.70	0.58	28.82	0.00	0.34	0.60	0.86	1.00
1.80	0.64	28.93	0.00	0.41	0.68	0.95	1.00
1.90	0.69	29.04	0.00	0.48	0.76	1.00	1.00
2.00	0.74	29.15	0.00	0.56	0.84	1.00	1.00

Table 52: Call option prices for March Nino 3.4 SST conditioned on IRI ensemble forecasts released in July

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	24.30	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	24.43	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.57	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.70	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.83	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.96	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	25.09	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	25.22	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	25.35	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.49	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.62	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.75	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.88	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	26.01	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	26.14	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	26.27	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.40	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.54	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.67	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	26.80	0.00	0.00	0.00	0.00	0.00
0.00	0.00	26.93	0.00	0.00	0.00	0.00	0.00
0.10	0.01	27.07	0.00	0.00	0.00	0.00	0.03
0.20	0.01	27.19	0.00	0.00	0.00	0.00	0.12
0.30	0.02	27.32	0.00	0.00	0.00	0.00	0.22
0.40	0.03	27.46	0.00	0.00	0.00	0.00	0.33
0.50	0.04	27.59	0.00	0.00	0.00	0.00	0.43
0.60	0.06	27.72	0.00	0.00	0.00	0.02	0.56
0.70	0.10	27.85	0.00	0.00	0.00	0.12	0.66
0.80	0.14	27.98	0.00	0.00	0.00	0.22	0.78
0.90	0.20	28.11	0.00	0.00	0.08	0.33	0.91
1.00	0.26	28.24	0.00	0.00	0.17	0.43	1.00
1.10	0.33	28.38	0.00	0.00	0.27	0.54	1.00
1.20	0.40	28.50	0.00	0.09	0.36	0.64	1.00
1.30	0.47	28.64	0.00	0.18	0.46	0.75	1.00
1.40	0.54	28.77	0.00	0.26	0.56	0.86	1.00
1.50	0.61	28.90	0.00	0.34	0.66	0.97	1.00
1.60	0.67	29.03	0.00	0.43	0.75	1.00	1.00
1.70	0.72	29.16	0.00	0.51	0.85	1.00	1.00
1.80	0.77	29.30	0.00	0.60	0.95	1.00	1.00
1.90	0.81	29.43	0.00	0.68	1.00	1.00	1.00
2.00	0.84	29.56	0.00	0.76	1.00	1.00	1.00

Table 53: Call option prices for March Nino 3.4 SST conditioned on IRI ensemble forecasts released in June

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	24.61	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	24.73	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.85	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.98	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	25.09	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	25.21	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	25.33	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	25.45	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	25.57	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.69	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.81	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.93	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	26.05	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	26.17	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	26.28	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	26.40	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.52	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.64	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.76	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	26.89	0.00	0.00	0.00	0.00	0.00
0.00	0.01	27.00	0.00	0.00	0.00	0.00	0.04
0.10	0.01	27.12	0.00	0.00	0.00	0.00	0.13
0.20	0.01	27.24	0.00	0.00	0.00	0.00	0.22
0.30	0.02	27.36	0.00	0.00	0.00	0.00	0.31
0.40	0.03	27.48	0.00	0.00	0.00	0.00	0.40
0.50	0.05	27.60	0.00	0.00	0.00	0.00	0.51
0.60	0.08	27.72	0.00	0.00	0.00	0.04	0.61
0.70	0.10	27.84	0.00	0.00	0.00	0.13	0.72
0.80	0.14	27.96	0.00	0.00	0.00	0.23	0.82
0.90	0.19	28.07	0.00	0.00	0.05	0.32	0.94
1.00	0.25	28.20	0.00	0.00	0.14	0.42	1.00
1.10	0.31	28.32	0.00	0.00	0.23	0.52	1.00
1.20	0.37	28.44	0.00	0.01	0.31	0.62	1.00
1.30	0.43	28.56	0.00	0.09	0.40	0.71	1.00
1.40	0.49	28.68	0.00	0.16	0.49	0.82	1.00
1.50	0.55	28.80	0.00	0.24	0.58	0.91	1.00
1.60	0.61	28.91	0.00	0.31	0.66	1.00	1.00
1.70	0.66	29.04	0.00	0.39	0.75	1.00	1.00
1.80	0.70	29.16	0.00	0.47	0.84	1.00	1.00
1.90	0.74	29.27	0.00	0.54	0.93	1.00	1.00
2.00	0.78	29.39	0.00	0.61	1.00	1.00	1.00

Table 54: Call option prices for March Nino 3.4 SST conditioned on IRI ensemble forecasts released in May

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	24.40	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	24.54	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.67	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.80	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.94	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	25.06	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	25.18	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	25.32	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	25.44	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.58	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.71	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.84	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.96	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	26.10	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	26.23	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	26.36	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.49	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.63	0.00	0.00	0.00	0.00	0.00
-0.20	0.01	26.75	0.00	0.00	0.00	0.00	0.00
-0.10	0.01	26.88	0.00	0.00	0.00	0.00	0.04
0.00	0.01	27.01	0.00	0.00	0.00	0.00	0.13
0.10	0.02	27.14	0.00	0.00	0.00	0.00	0.23
0.20	0.02	27.27	0.00	0.00	0.00	0.00	0.32
0.30	0.03	27.40	0.00	0.00	0.00	0.00	0.43
0.40	0.05	27.53	0.00	0.00	0.00	0.00	0.53
0.50	0.07	27.66	0.00	0.00	0.00	0.02	0.64
0.60	0.11	27.79	0.00	0.00	0.00	0.12	0.77
0.70	0.15	27.93	0.00	0.00	0.00	0.23	0.90
0.80	0.20	28.06	0.00	0.00	0.04	0.34	1.00
0.90	0.26	28.19	0.00	0.00	0.13	0.45	1.00
1.00	0.32	28.31	0.00	0.00	0.23	0.55	1.00
1.10	0.38	28.44	0.00	0.00	0.32	0.66	1.00
1.20	0.45	28.57	0.00	0.06	0.41	0.77	1.00
1.30	0.51	28.71	0.00	0.14	0.52	0.89	1.00
1.40	0.57	28.84	0.00	0.22	0.61	1.00	1.00
1.50	0.62	28.97	0.00	0.30	0.71	1.00	1.00
1.60	0.67	29.10	0.00	0.38	0.80	1.00	1.00
1.70	0.71	29.22	0.00	0.46	0.90	1.00	1.00
1.80	0.74	29.35	0.00	0.53	0.99	1.00	1.00
1.90	0.77	29.48	0.00	0.61	1.00	1.00	1.00
2.00	0.80	29.62	0.00	0.69	1.00	1.00	1.00

Table 55: Put option prices for March Nino 3.4 SST conditioned on IRI ensemble forecasts released in January

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.71	25.66	0.25	0.58	0.73	0.88	1.00
-1.90	0.66	25.73	0.20	0.53	0.67	0.82	1.00
-1.80	0.61	25.81	0.15	0.47	0.62	0.76	1.00
-1.70	0.56	25.89	0.10	0.42	0.56	0.70	1.00
-1.60	0.51	25.96	0.05	0.37	0.51	0.64	0.96
-1.50	0.45	26.04	0.01	0.31	0.45	0.59	0.90
-1.40	0.40	26.12	0.00	0.26	0.39	0.53	0.83
-1.30	0.34	26.19	0.00	0.20	0.34	0.47	0.76
-1.20	0.29	26.27	0.00	0.15	0.28	0.41	0.70
-1.10	0.24	26.35	0.00	0.09	0.22	0.35	0.64
-1.00	0.19	26.42	0.00	0.04	0.17	0.29	0.58
-0.90	0.15	26.50	0.00	0.00	0.11	0.24	0.52
-0.80	0.11	26.58	0.00	0.00	0.05	0.18	0.46
-0.70	0.07	26.65	0.00	0.00	0.00	0.12	0.40
-0.60	0.05	26.73	0.00	0.00	0.00	0.06	0.34
-0.50	0.03	26.80	0.00	0.00	0.00	0.01	0.28
-0.40	0.02	26.88	0.00	0.00	0.00	0.00	0.22
-0.30	0.01	26.96	0.00	0.00	0.00	0.00	0.16
-0.20	0.01	27.03	0.00	0.00	0.00	0.00	0.11
-0.10	0.00	27.11	0.00	0.00	0.00	0.00	0.05
0.00	0.00	27.19	0.00	0.00	0.00	0.00	0.00
0.10	0.00	27.26	0.00	0.00	0.00	0.00	0.00
0.20	0.00	27.34	0.00	0.00	0.00	0.00	0.00
0.30	0.00	27.42	0.00	0.00	0.00	0.00	0.00
0.40	0.00	27.49	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.57	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.65	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.73	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.80	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.88	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.95	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.03	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.11	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.18	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.26	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.33	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.41	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.49	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.56	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.64	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.72	0.00	0.00	0.00	0.00	0.00

Table 56: Put option prices for March Nino 3.4 SST conditioned on IRI ensemble forecasts released in December

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.72	25.63	0.15	0.57	0.75	0.93	1.00
-1.90	0.68	25.70	0.11	0.52	0.70	0.88	1.00
-1.80	0.63	25.78	0.06	0.46	0.64	0.82	1.00
-1.70	0.58	25.85	0.01	0.41	0.59	0.76	1.00
-1.60	0.53	25.93	0.00	0.36	0.53	0.70	1.00
-1.50	0.48	26.00	0.00	0.31	0.48	0.64	1.00
-1.40	0.42	26.08	0.00	0.25	0.42	0.58	0.96
-1.30	0.37	26.16	0.00	0.20	0.36	0.53	0.89
-1.20	0.33	26.23	0.00	0.15	0.31	0.47	0.84
-1.10	0.27	26.31	0.00	0.09	0.25	0.41	0.76
-1.00	0.23	26.38	0.00	0.04	0.20	0.36	0.71
-0.90	0.19	26.45	0.00	0.00	0.14	0.30	0.64
-0.80	0.15	26.53	0.00	0.00	0.09	0.24	0.58
-0.70	0.11	26.61	0.00	0.00	0.03	0.18	0.52
-0.60	0.08	26.68	0.00	0.00	0.00	0.13	0.46
-0.50	0.06	26.75	0.00	0.00	0.00	0.07	0.40
-0.40	0.04	26.83	0.00	0.00	0.00	0.02	0.34
-0.30	0.03	26.90	0.00	0.00	0.00	0.00	0.29
-0.20	0.02	26.98	0.00	0.00	0.00	0.00	0.23
-0.10	0.01	27.05	0.00	0.00	0.00	0.00	0.18
0.00	0.01	27.13	0.00	0.00	0.00	0.00	0.12
0.10	0.01	27.20	0.00	0.00	0.00	0.00	0.07
0.20	0.00	27.28	0.00	0.00	0.00	0.00	0.01
0.30	0.00	27.36	0.00	0.00	0.00	0.00	0.00
0.40	0.00	27.43	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.51	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.58	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.66	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.73	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.80	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.88	0.00	0.00	0.00	0.00	0.00
1.10	0.00	27.96	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.03	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.11	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.18	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.26	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.33	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.41	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.48	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.56	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.63	0.00	0.00	0.00	0.00	0.00

Table 57: Put option prices for March Nino 3.4 SST conditioned on IRI ensemble forecasts released in November

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.76	25.53	0.09	0.60	0.83	1.00	1.00
-1.90	0.72	25.60	0.05	0.55	0.77	0.99	1.00
-1.80	0.68	25.68	0.01	0.50	0.71	0.93	1.00
-1.70	0.63	25.76	0.00	0.44	0.65	0.87	1.00
-1.60	0.59	25.83	0.00	0.39	0.60	0.81	1.00
-1.50	0.54	25.91	0.00	0.34	0.54	0.75	1.00
-1.40	0.48	26.00	0.00	0.28	0.48	0.68	1.00
-1.30	0.44	26.07	0.00	0.23	0.43	0.62	1.00
-1.20	0.38	26.15	0.00	0.17	0.37	0.56	1.00
-1.10	0.33	26.23	0.00	0.12	0.31	0.50	0.93
-1.00	0.28	26.31	0.00	0.07	0.25	0.44	0.86
-0.90	0.24	26.38	0.00	0.01	0.20	0.38	0.80
-0.80	0.20	26.46	0.00	0.00	0.14	0.32	0.73
-0.70	0.16	26.54	0.00	0.00	0.08	0.26	0.66
-0.60	0.12	26.62	0.00	0.00	0.02	0.20	0.60
-0.50	0.09	26.69	0.00	0.00	0.00	0.14	0.54
-0.40	0.07	26.77	0.00	0.00	0.00	0.08	0.47
-0.30	0.05	26.85	0.00	0.00	0.00	0.03	0.41
-0.20	0.04	26.93	0.00	0.00	0.00	0.00	0.36
-0.10	0.03	27.01	0.00	0.00	0.00	0.00	0.30
0.00	0.02	27.08	0.00	0.00	0.00	0.00	0.24
0.10	0.01	27.16	0.00	0.00	0.00	0.00	0.18
0.20	0.01	27.24	0.00	0.00	0.00	0.00	0.12
0.30	0.01	27.32	0.00	0.00	0.00	0.00	0.07
0.40	0.00	27.39	0.00	0.00	0.00	0.00	0.02
0.50	0.00	27.47	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.55	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.63	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.71	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.78	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.86	0.00	0.00	0.00	0.00	0.00
1.10	0.00	27.94	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.02	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.10	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.17	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.25	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.33	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.41	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.48	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.56	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.64	0.00	0.00	0.00	0.00	0.00

Table 58: Put option prices for March Nino 3.4 SST conditioned on IRI ensemble forecasts released in October

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.80	25.39	0.06	0.66	0.93	1.00	1.00
-1.90	0.77	25.48	0.02	0.61	0.86	1.00	1.00
-1.80	0.73	25.56	0.00	0.55	0.80	1.00	1.00
-1.70	0.69	25.64	0.00	0.50	0.74	0.99	1.00
-1.60	0.64	25.72	0.00	0.44	0.68	0.92	1.00
-1.50	0.60	25.80	0.00	0.38	0.62	0.86	1.00
-1.40	0.55	25.89	0.00	0.33	0.56	0.79	1.00
-1.30	0.50	25.97	0.00	0.27	0.50	0.73	1.00
-1.20	0.45	26.06	0.00	0.22	0.44	0.66	1.00
-1.10	0.39	26.14	0.00	0.16	0.38	0.59	1.00
-1.00	0.34	26.22	0.00	0.10	0.32	0.52	1.00
-0.90	0.29	26.31	0.00	0.04	0.25	0.46	0.93
-0.80	0.24	26.39	0.00	0.00	0.19	0.39	0.85
-0.70	0.20	26.47	0.00	0.00	0.13	0.33	0.79
-0.60	0.16	26.55	0.00	0.00	0.07	0.27	0.72
-0.50	0.13	26.64	0.00	0.00	0.01	0.20	0.66
-0.40	0.10	26.72	0.00	0.00	0.00	0.14	0.58
-0.30	0.07	26.81	0.00	0.00	0.00	0.08	0.52
-0.20	0.05	26.89	0.00	0.00	0.00	0.02	0.45
-0.10	0.04	26.98	0.00	0.00	0.00	0.00	0.38
0.00	0.03	27.05	0.00	0.00	0.00	0.00	0.33
0.10	0.02	27.14	0.00	0.00	0.00	0.00	0.27
0.20	0.01	27.22	0.00	0.00	0.00	0.00	0.19
0.30	0.01	27.31	0.00	0.00	0.00	0.00	0.13
0.40	0.01	27.39	0.00	0.00	0.00	0.00	0.08
0.50	0.00	27.48	0.00	0.00	0.00	0.00	0.02
0.60	0.00	27.56	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.64	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.72	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.81	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.89	0.00	0.00	0.00	0.00	0.00
1.10	0.00	27.98	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.06	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.14	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.23	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.31	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.39	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.48	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.56	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.64	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.73	0.00	0.00	0.00	0.00	0.00

Table 59: Put option prices for March Nino 3.4 SST conditioned on IRI ensemble forecasts released in September

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.89	25.04	0.17	0.87	1.00	1.00	1.00
-1.90	0.87	25.13	0.12	0.81	1.00	1.00	1.00
-1.80	0.84	25.23	0.08	0.74	1.00	1.00	1.00
-1.70	0.81	25.33	0.03	0.68	0.97	1.00	1.00
-1.60	0.78	25.43	0.00	0.62	0.90	1.00	1.00
-1.50	0.74	25.53	0.00	0.55	0.83	1.00	1.00
-1.40	0.69	25.62	0.00	0.49	0.76	1.00	1.00
-1.30	0.64	25.72	0.00	0.42	0.68	0.94	1.00
-1.20	0.59	25.82	0.00	0.36	0.61	0.86	1.00
-1.10	0.53	25.92	0.00	0.29	0.54	0.79	1.00
-1.00	0.47	26.01	0.00	0.23	0.47	0.71	1.00
-0.90	0.41	26.11	0.00	0.16	0.40	0.63	1.00
-0.80	0.35	26.21	0.00	0.09	0.32	0.55	1.00
-0.70	0.30	26.31	0.00	0.03	0.25	0.48	0.97
-0.60	0.24	26.40	0.00	0.00	0.18	0.40	0.90
-0.50	0.19	26.50	0.00	0.00	0.11	0.32	0.81
-0.40	0.15	26.60	0.00	0.00	0.04	0.25	0.72
-0.30	0.11	26.70	0.00	0.00	0.00	0.17	0.64
-0.20	0.08	26.79	0.00	0.00	0.00	0.10	0.56
-0.10	0.06	26.89	0.00	0.00	0.00	0.02	0.48
0.00	0.04	26.99	0.00	0.00	0.00	0.00	0.40
0.10	0.03	27.08	0.00	0.00	0.00	0.00	0.33
0.20	0.02	27.19	0.00	0.00	0.00	0.00	0.26
0.30	0.01	27.28	0.00	0.00	0.00	0.00	0.19
0.40	0.01	27.38	0.00	0.00	0.00	0.00	0.13
0.50	0.01	27.48	0.00	0.00	0.00	0.00	0.06
0.60	0.00	27.57	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.67	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.77	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.87	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.97	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.06	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.16	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.26	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.36	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.45	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.55	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.65	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.75	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.85	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.94	0.00	0.00	0.00	0.00	0.00

Table 60: Put option prices for March Nino 3.4 SST conditioned on IRI ensemble forecasts released in August

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.94	24.75	0.35	1.00	1.00	1.00	1.00
-1.90	0.93	24.86	0.31	1.00	1.00	1.00	1.00
-1.80	0.91	24.97	0.26	0.94	1.00	1.00	1.00
-1.70	0.89	25.08	0.22	0.87	1.00	1.00	1.00
-1.60	0.86	25.19	0.16	0.79	1.00	1.00	1.00
-1.50	0.83	25.30	0.10	0.72	0.99	1.00	1.00
-1.40	0.79	25.41	0.04	0.65	0.92	1.00	1.00
-1.30	0.75	25.52	0.00	0.58	0.83	1.00	1.00
-1.20	0.69	25.63	0.00	0.50	0.75	1.00	1.00
-1.10	0.63	25.74	0.00	0.42	0.67	0.91	1.00
-1.00	0.57	25.85	0.00	0.35	0.59	0.82	1.00
-0.90	0.51	25.96	0.00	0.28	0.51	0.74	1.00
-0.80	0.44	26.07	0.00	0.20	0.42	0.65	1.00
-0.70	0.37	26.18	0.00	0.13	0.35	0.57	1.00
-0.60	0.30	26.29	0.00	0.05	0.27	0.48	0.95
-0.50	0.24	26.40	0.00	0.00	0.19	0.39	0.86
-0.40	0.18	26.51	0.00	0.00	0.10	0.31	0.76
-0.30	0.14	26.62	0.00	0.00	0.02	0.22	0.67
-0.20	0.10	26.73	0.00	0.00	0.00	0.14	0.58
-0.10	0.06	26.84	0.00	0.00	0.00	0.06	0.49
0.00	0.04	26.95	0.00	0.00	0.00	0.00	0.40
0.10	0.03	27.06	0.00	0.00	0.00	0.00	0.33
0.20	0.02	27.17	0.00	0.00	0.00	0.00	0.25
0.30	0.01	27.28	0.00	0.00	0.00	0.00	0.17
0.40	0.01	27.39	0.00	0.00	0.00	0.00	0.08
0.50	0.01	27.50	0.00	0.00	0.00	0.00	0.02
0.60	0.00	27.61	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.72	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.83	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.94	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.05	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.16	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.27	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.38	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.49	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.60	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.71	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.82	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.93	0.00	0.00	0.00	0.00	0.00
1.90	0.00	29.04	0.00	0.00	0.00	0.00	0.00
2.00	0.00	29.15	0.00	0.00	0.00	0.00	0.00

Table 61: Put option prices for March Nino 3.4 SST conditioned on IRI ensemble forecasts released in July

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.95	24.30	0.34	1.00	1.00	1.00	1.00
-1.90	0.94	24.43	0.27	1.00	1.00	1.00	1.00
-1.80	0.93	24.57	0.23	1.00	1.00	1.00	1.00
-1.70	0.92	24.70	0.17	1.00	1.00	1.00	1.00
-1.60	0.91	24.83	0.11	0.98	1.00	1.00	1.00
-1.50	0.89	24.96	0.08	0.89	1.00	1.00	1.00
-1.40	0.86	25.09	0.04	0.82	1.00	1.00	1.00
-1.30	0.83	25.22	0.00	0.74	1.00	1.00	1.00
-1.20	0.79	25.35	0.00	0.64	0.96	1.00	1.00
-1.10	0.74	25.49	0.00	0.56	0.86	1.00	1.00
-1.00	0.69	25.62	0.00	0.47	0.76	1.00	1.00
-0.90	0.62	25.75	0.00	0.39	0.67	0.94	1.00
-0.80	0.55	25.88	0.00	0.30	0.57	0.84	1.00
-0.70	0.48	26.01	0.00	0.22	0.47	0.73	1.00
-0.60	0.40	26.14	0.00	0.13	0.38	0.63	1.00
-0.50	0.33	26.27	0.00	0.04	0.28	0.52	1.00
-0.40	0.25	26.40	0.00	0.00	0.19	0.42	0.95
-0.30	0.19	26.54	0.00	0.00	0.09	0.31	0.83
-0.20	0.13	26.67	0.00	0.00	0.00	0.21	0.72
-0.10	0.09	26.80	0.00	0.00	0.00	0.11	0.60
0.00	0.06	26.93	0.00	0.00	0.00	0.01	0.51
0.10	0.04	27.07	0.00	0.00	0.00	0.00	0.41
0.20	0.02	27.19	0.00	0.00	0.00	0.00	0.32
0.30	0.02	27.32	0.00	0.00	0.00	0.00	0.23
0.40	0.01	27.46	0.00	0.00	0.00	0.00	0.13
0.50	0.01	27.59	0.00	0.00	0.00	0.00	0.06
0.60	0.01	27.72	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.85	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.98	0.00	0.00	0.00	0.00	0.00
0.90	0.00	28.11	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.24	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.38	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.50	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.64	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.77	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.90	0.00	0.00	0.00	0.00	0.00
1.60	0.00	29.03	0.00	0.00	0.00	0.00	0.00
1.70	0.00	29.16	0.00	0.00	0.00	0.00	0.00
1.80	0.00	29.30	0.00	0.00	0.00	0.00	0.00
1.90	0.00	29.43	0.00	0.00	0.00	0.00	0.00
2.00	0.00	29.56	0.00	0.00	0.00	0.00	0.00

Table 62: Put option prices for March Nino 3.4 SST conditioned on IRI ensemble forecasts released in June

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.91	24.61	0.06	1.00	1.00	1.00	1.00
-1.90	0.90	24.73	0.00	0.99	1.00	1.00	1.00
-1.80	0.88	24.85	0.00	0.92	1.00	1.00	1.00
-1.70	0.86	24.98	0.00	0.83	1.00	1.00	1.00
-1.60	0.84	25.09	0.00	0.76	1.00	1.00	1.00
-1.50	0.81	25.21	0.00	0.69	1.00	1.00	1.00
-1.40	0.78	25.33	0.00	0.61	0.98	1.00	1.00
-1.30	0.74	25.45	0.00	0.54	0.88	1.00	1.00
-1.20	0.69	25.57	0.00	0.46	0.80	1.00	1.00
-1.10	0.64	25.69	0.00	0.38	0.71	1.00	1.00
-1.00	0.59	25.81	0.00	0.31	0.62	0.93	1.00
-0.90	0.52	25.93	0.00	0.24	0.54	0.83	1.00
-0.80	0.46	26.05	0.00	0.15	0.44	0.74	1.00
-0.70	0.39	26.17	0.00	0.07	0.36	0.63	1.00
-0.60	0.33	26.28	0.00	0.00	0.27	0.54	1.00
-0.50	0.26	26.40	0.00	0.00	0.18	0.45	1.00
-0.40	0.21	26.52	0.00	0.00	0.09	0.35	0.92
-0.30	0.16	26.64	0.00	0.00	0.01	0.25	0.82
-0.20	0.12	26.76	0.00	0.00	0.00	0.16	0.73
-0.10	0.08	26.89	0.00	0.00	0.00	0.07	0.61
0.00	0.06	27.00	0.00	0.00	0.00	0.00	0.53
0.10	0.04	27.12	0.00	0.00	0.00	0.00	0.43
0.20	0.03	27.24	0.00	0.00	0.00	0.00	0.34
0.30	0.02	27.36	0.00	0.00	0.00	0.00	0.26
0.40	0.01	27.48	0.00	0.00	0.00	0.00	0.17
0.50	0.01	27.60	0.00	0.00	0.00	0.00	0.11
0.60	0.01	27.72	0.00	0.00	0.00	0.00	0.03
0.70	0.01	27.84	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.96	0.00	0.00	0.00	0.00	0.00
0.90	0.00	28.07	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.20	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.32	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.44	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.56	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.68	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.80	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.91	0.00	0.00	0.00	0.00	0.00
1.70	0.00	29.04	0.00	0.00	0.00	0.00	0.00
1.80	0.00	29.16	0.00	0.00	0.00	0.00	0.00
1.90	0.00	29.27	0.00	0.00	0.00	0.00	0.00
2.00	0.00	29.39	0.00	0.00	0.00	0.00	0.00

Table 63: Put option prices for March Nino 3.4 SST conditioned on IRI ensemble forecasts released in May

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.90	24.40	0.00	1.00	1.00	1.00	1.00
-1.90	0.89	24.54	0.00	1.00	1.00	1.00	1.00
-1.80	0.88	24.67	0.00	0.96	1.00	1.00	1.00
-1.70	0.86	24.80	0.00	0.88	1.00	1.00	1.00
-1.60	0.84	24.94	0.00	0.80	1.00	1.00	1.00
-1.50	0.82	25.06	0.00	0.73	1.00	1.00	1.00
-1.40	0.79	25.18	0.00	0.66	1.00	1.00	1.00
-1.30	0.76	25.32	0.00	0.57	0.98	1.00	1.00
-1.20	0.72	25.44	0.00	0.49	0.89	1.00	1.00
-1.10	0.67	25.58	0.00	0.41	0.79	1.00	1.00
-1.00	0.62	25.71	0.00	0.33	0.70	1.00	1.00
-0.90	0.57	25.84	0.00	0.25	0.60	0.95	1.00
-0.80	0.50	25.96	0.00	0.17	0.51	0.84	1.00
-0.70	0.44	26.10	0.00	0.09	0.41	0.73	1.00
-0.60	0.37	26.23	0.00	0.00	0.31	0.62	1.00
-0.50	0.30	26.36	0.00	0.00	0.22	0.51	1.00
-0.40	0.24	26.49	0.00	0.00	0.12	0.41	1.00
-0.30	0.18	26.63	0.00	0.00	0.02	0.30	0.92
-0.20	0.13	26.75	0.00	0.00	0.00	0.19	0.81
-0.10	0.09	26.88	0.00	0.00	0.00	0.10	0.69
0.00	0.07	27.01	0.00	0.00	0.00	0.00	0.59
0.10	0.05	27.14	0.00	0.00	0.00	0.00	0.49
0.20	0.03	27.27	0.00	0.00	0.00	0.00	0.39
0.30	0.02	27.40	0.00	0.00	0.00	0.00	0.32
0.40	0.02	27.53	0.00	0.00	0.00	0.00	0.22
0.50	0.01	27.66	0.00	0.00	0.00	0.00	0.15
0.60	0.01	27.79	0.00	0.00	0.00	0.00	0.09
0.70	0.01	27.93	0.00	0.00	0.00	0.00	0.02
0.80	0.01	28.06	0.00	0.00	0.00	0.00	0.00
0.90	0.01	28.19	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.31	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.44	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.57	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.71	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.84	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.97	0.00	0.00	0.00	0.00	0.00
1.60	0.00	29.10	0.00	0.00	0.00	0.00	0.00
1.70	0.00	29.22	0.00	0.00	0.00	0.00	0.00
1.80	0.00	29.35	0.00	0.00	0.00	0.00	0.00
1.90	0.00	29.48	0.00	0.00	0.00	0.00	0.00
2.00	0.00	29.62	0.00	0.00	0.00	0.00	0.00

Appendix G: April Pricing

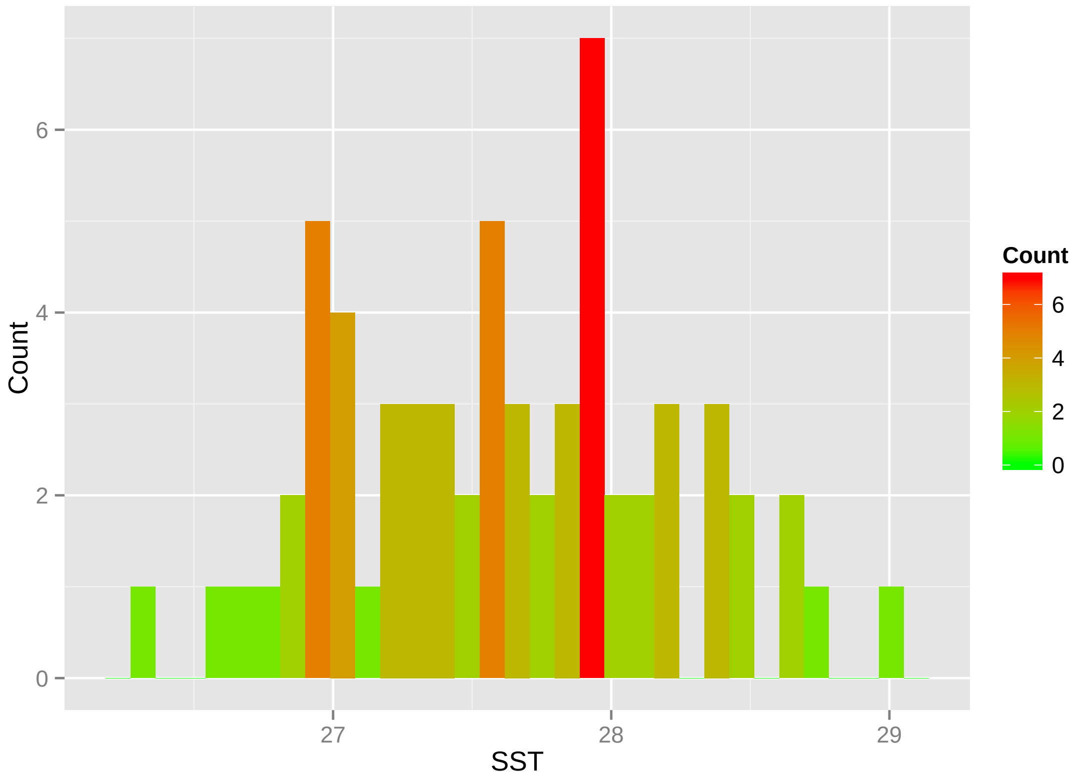


Figure 47: Histogram of April SST for Niño 3.4 ERSST.3b

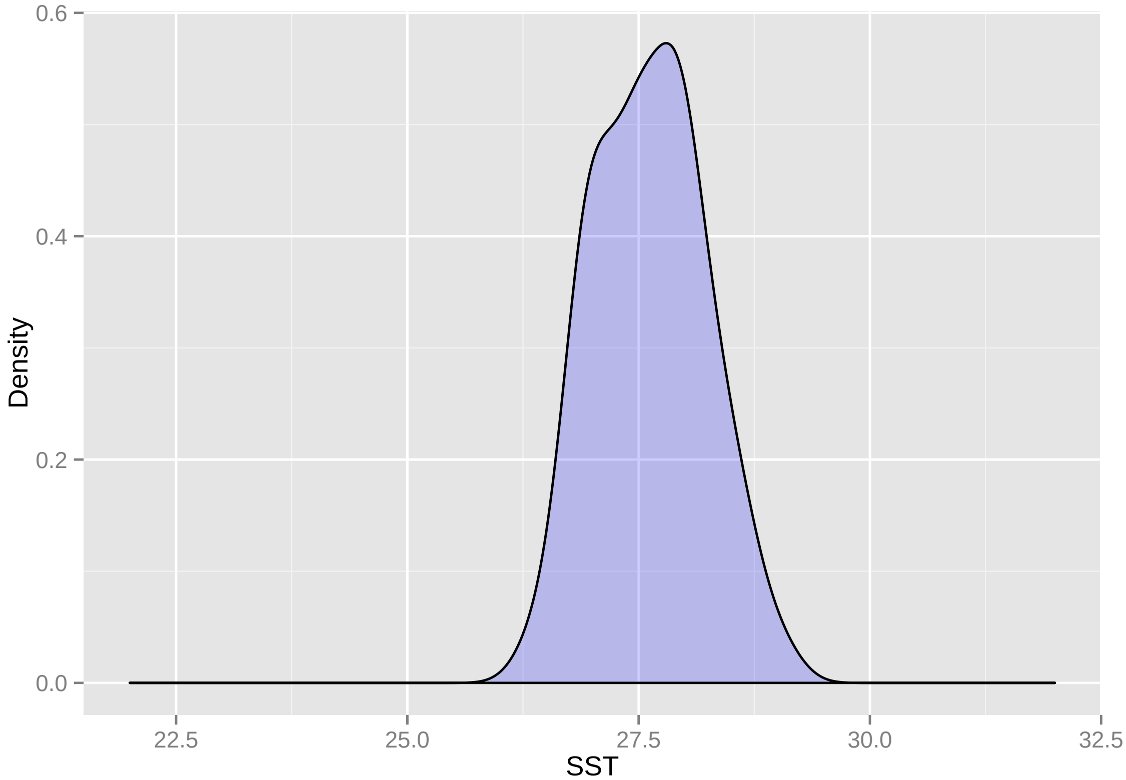


Figure 48: Kernel density estimate of April SST for Niño 3.4 ERSST.3b

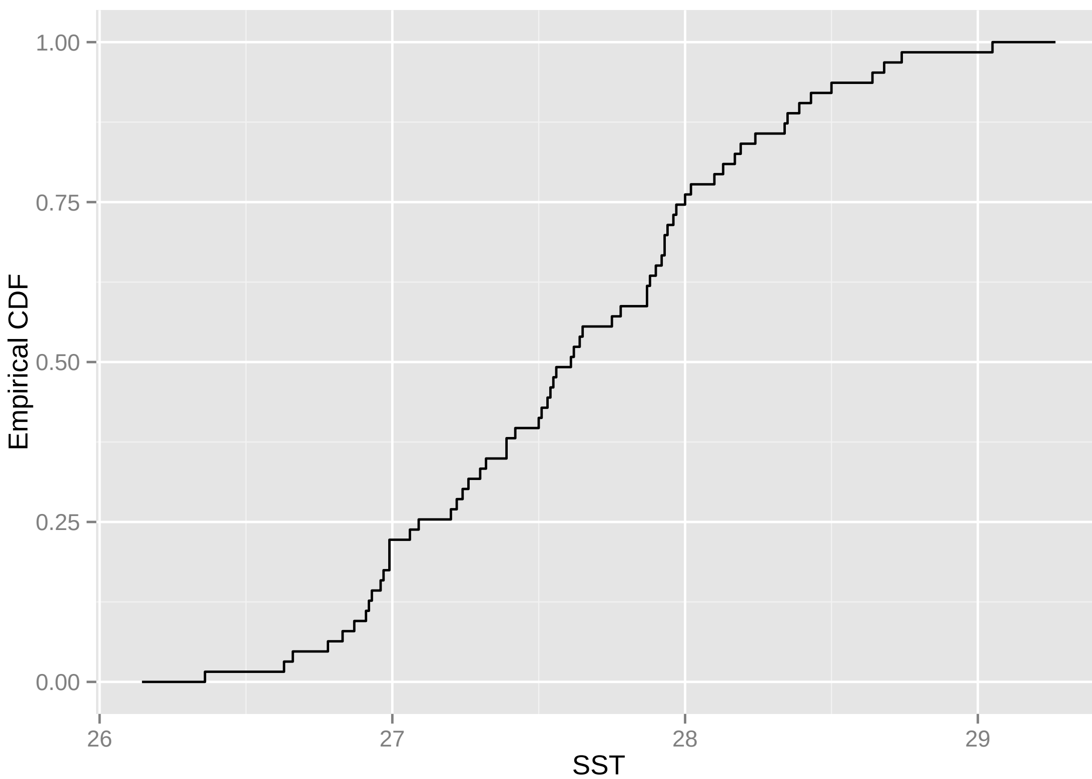


Figure 49: ECDF of April SST for Niño 3.4 ERSST.3b

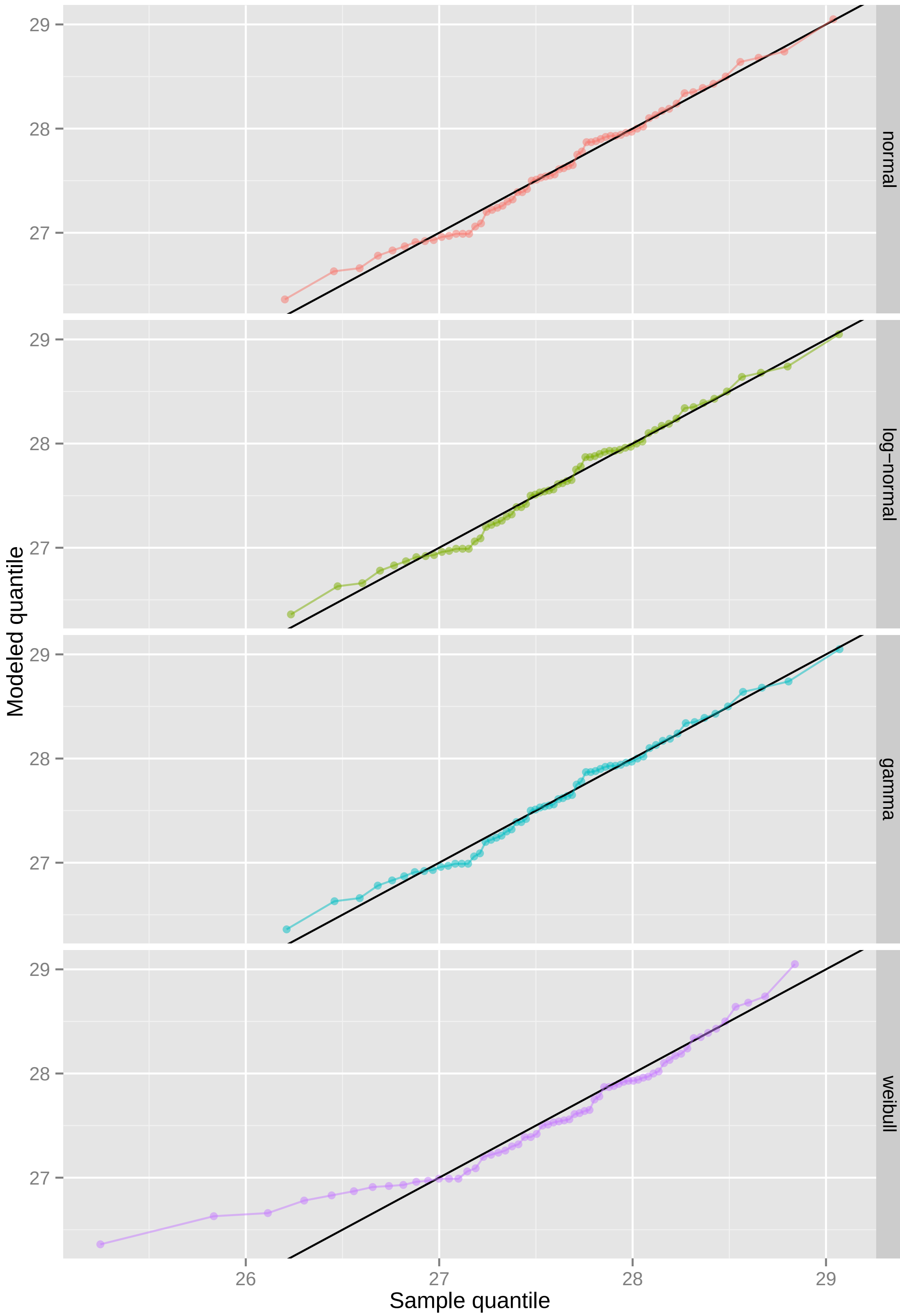


Figure 50: QQ plots of April SST for Niño 3.4 ERSST.3b compared to samples from various distributions (n=2 million)

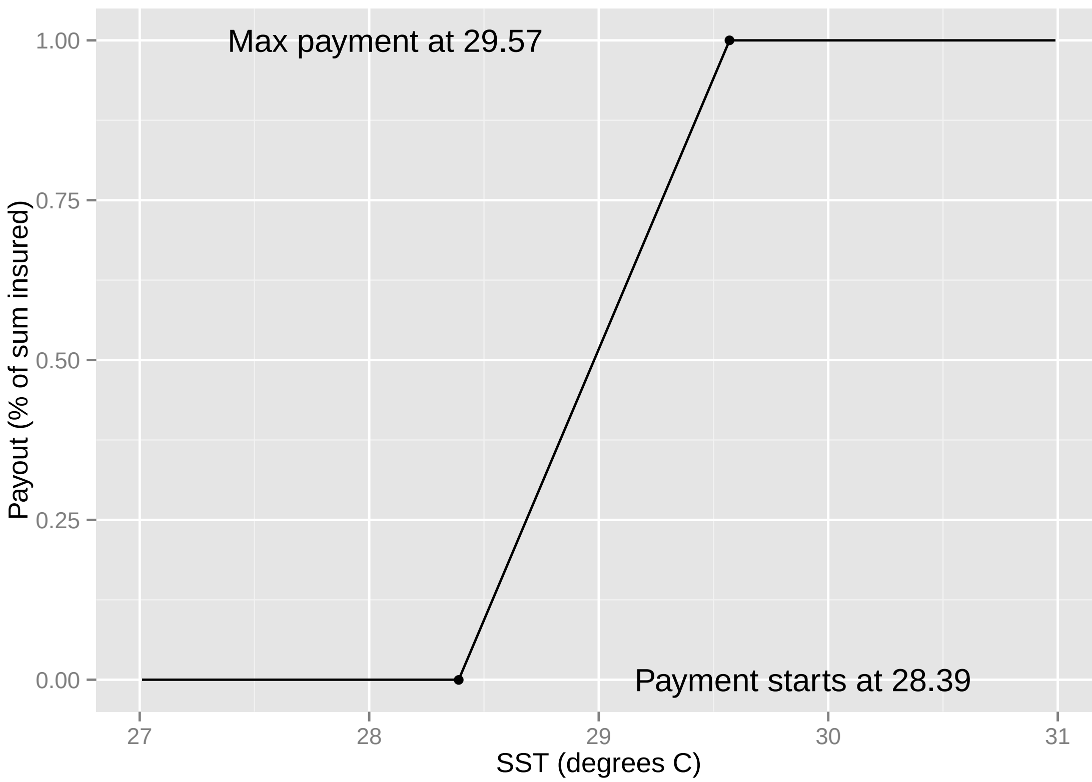


Figure 51: Payout function for call option on April SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations above the baseline

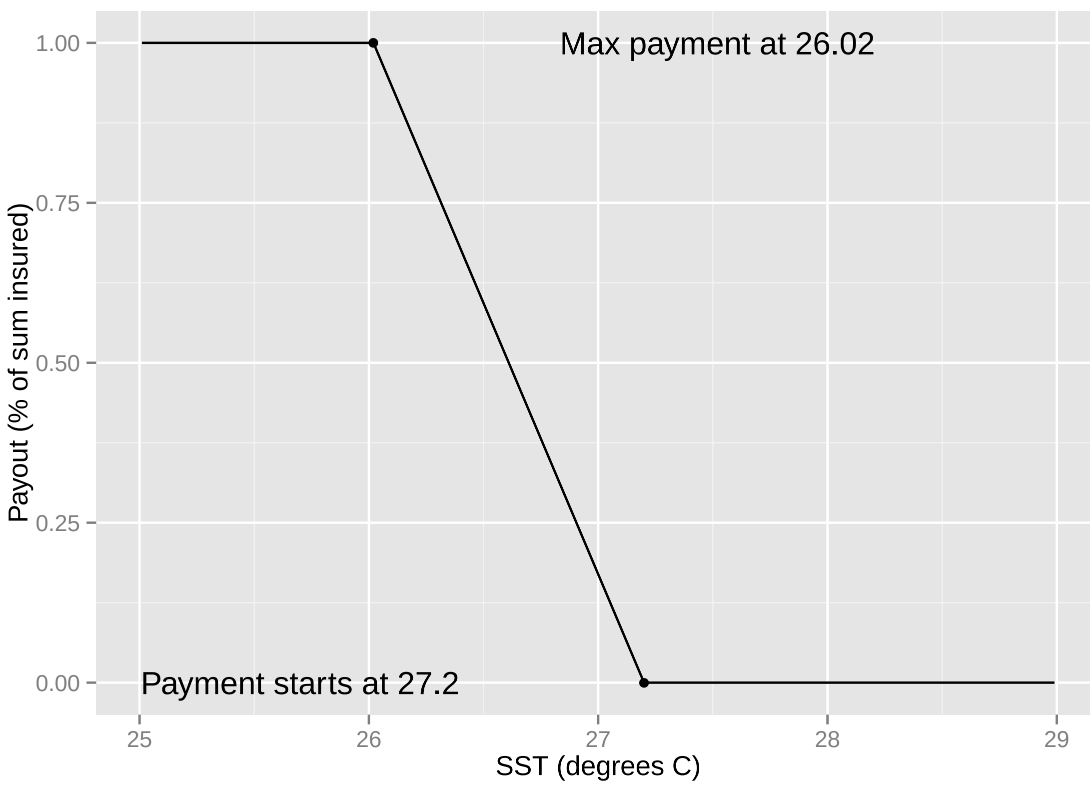


Figure 52: Payout function for put option on April SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

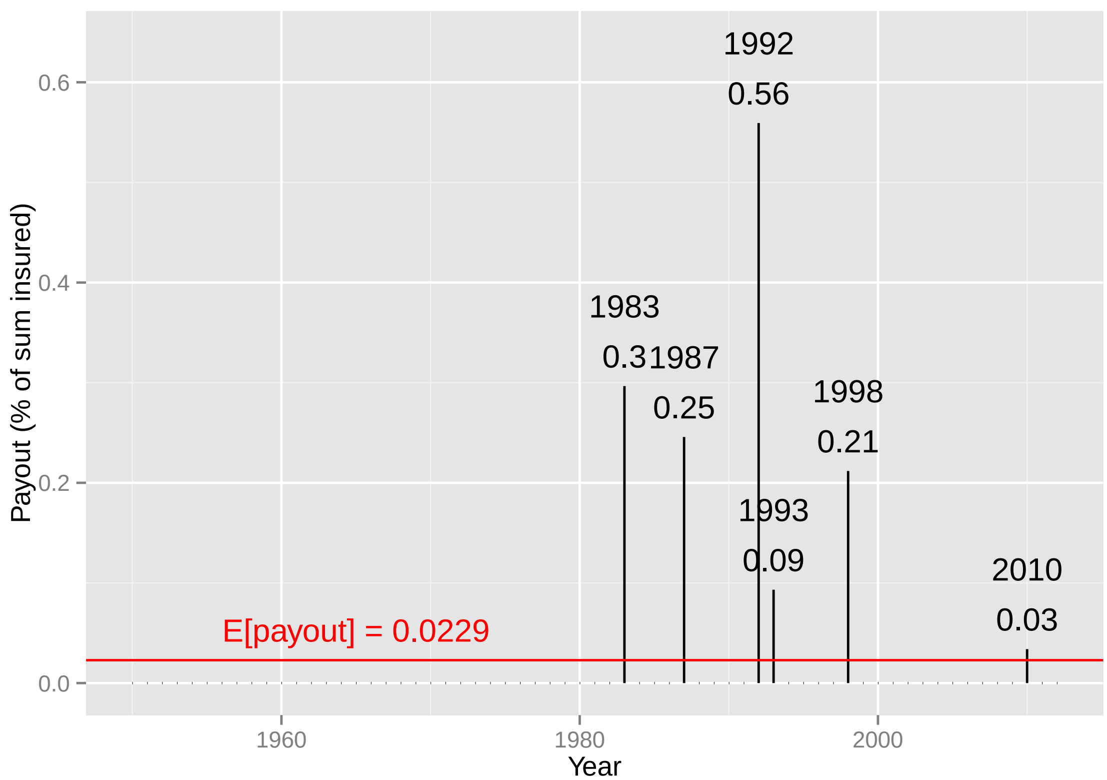


Figure 53: Historical burn on call option for April SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations above the baseline

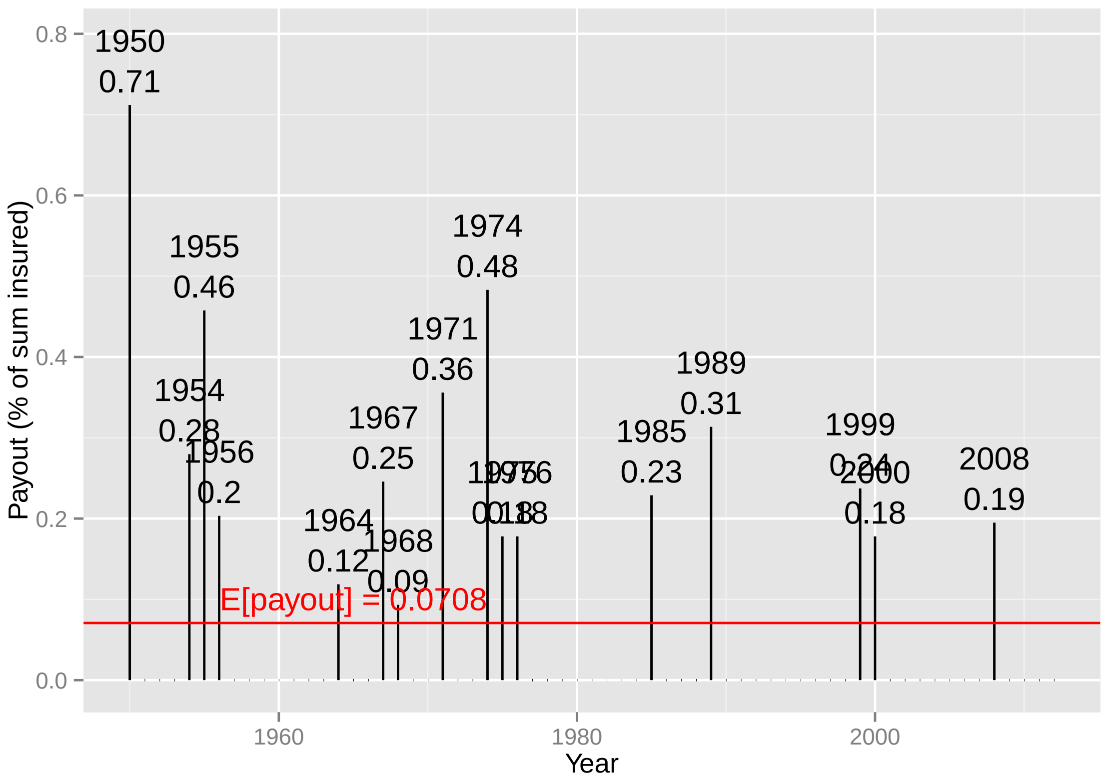


Figure 54: Historical burn on put option on April SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

Table 64: Bayesian regression linking April Niño 3.4 SST anomalies to average of relevant IRI ensemble forecasts

	mean	sd	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q	n_eff	Rhat
February forecast average covering April Niño 3.4 SST anomalies									
α	-0.10	0.10	-0.30	-0.20	-0.10	-0.10	0.00	91832	1
β	0.60	0.10	0.40	0.50	0.60	0.70	0.90	92801	1
σ_y^2	0.10	0.00	0.00	0.00	0.00	0.10	0.20	51134	1
January forecast average covering April Niño 3.4 SST anomalies									
α	-0.10	0.10	-0.30	-0.20	-0.10	-0.10	0.00	96784	1
β	0.50	0.10	0.30	0.50	0.50	0.60	0.80	92848	1
σ_y^2	0.10	0.00	0.00	0.00	0.10	0.10	0.20	55083	1
December forecast average covering April Niño 3.4 SST anomalies									
α	-0.20	0.10	-0.30	-0.20	-0.20	-0.10	0.00	96652	1
β	0.50	0.10	0.20	0.40	0.50	0.60	0.80	94077	1
σ_y^2	0.10	0.10	0.00	0.10	0.10	0.10	0.20	57158	1
November forecast average covering April Niño 3.4 SST anomalies									
α	-0.20	0.10	-0.40	-0.30	-0.20	-0.10	0.00	95978	1
β	0.50	0.20	0.20	0.40	0.50	0.60	0.80	92483	1
σ_y^2	0.10	0.10	0.00	0.10	0.10	0.10	0.30	56411	1
October forecast average covering April Niño 3.4 SST anomalies									
α	-0.20	0.10	-0.40	-0.30	-0.20	-0.10	0.00	94127	1
β	0.50	0.20	0.20	0.40	0.50	0.70	0.90	90541	1
σ_y^2	0.10	0.10	0.00	0.10	0.10	0.10	0.30	57704	1
September forecast average covering April Niño 3.4 SST anomalies									
α	-0.20	0.10	-0.50	-0.30	-0.20	-0.20	0.00	88319	1
β	0.70	0.20	0.20	0.50	0.70	0.80	1.10	84552	1
σ_y^2	0.10	0.10	0.00	0.10	0.10	0.10	0.30	56645	1
August forecast average covering April Niño 3.4 SST anomalies									
α	-0.30	0.10	-0.50	-0.30	-0.30	-0.20	0.00	85537	1
β	0.70	0.30	0.10	0.50	0.70	0.90	1.20	82379	1
σ_y^2	0.10	0.10	0.00	0.10	0.10	0.10	0.30	52947	1
July forecast average covering April Niño 3.4 SST anomalies									
α	-0.30	0.10	-0.50	-0.40	-0.30	-0.20	0.00	83531	1
β	0.70	0.30	0.00	0.50	0.70	0.90	1.40	80660	1
σ_y^2	0.10	0.10	0.00	0.10	0.10	0.20	0.40	54489	1
June forecast average covering April Niño 3.4 SST anomalies									
α	-0.20	0.10	-0.50	-0.30	-0.20	-0.10	0.00	93474	1
β	0.60	0.30	-0.10	0.40	0.60	0.80	1.30	85514	1
σ_y^2	0.20	0.10	0.10	0.10	0.10	0.20	0.40	55300	1

Table 65: Call option prices for April Nino 3.4 SST conditioned on IRI ensemble forecasts released in February

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	26.47	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	26.53	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	26.59	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	26.65	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	26.71	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	26.77	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	26.83	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	26.89	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	26.95	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	27.01	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	27.08	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	27.14	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	27.20	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	27.26	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	27.32	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	27.38	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	27.44	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	27.50	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	27.57	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	27.63	0.00	0.00	0.00	0.00	0.00
0.00	0.00	27.69	0.00	0.00	0.00	0.00	0.00
0.10	0.00	27.75	0.00	0.00	0.00	0.00	0.00
0.20	0.00	27.81	0.00	0.00	0.00	0.00	0.00
0.30	0.00	27.87	0.00	0.00	0.00	0.00	0.00
0.40	0.00	27.93	0.00	0.00	0.00	0.00	0.03
0.50	0.01	27.99	0.00	0.00	0.00	0.00	0.08
0.60	0.01	28.05	0.00	0.00	0.00	0.00	0.14
0.70	0.02	28.11	0.00	0.00	0.00	0.00	0.20
0.80	0.02	28.17	0.00	0.00	0.00	0.00	0.26
0.90	0.04	28.24	0.00	0.00	0.00	0.01	0.33
1.00	0.05	28.30	0.00	0.00	0.00	0.06	0.39
1.10	0.08	28.36	0.00	0.00	0.00	0.11	0.44
1.20	0.10	28.42	0.00	0.00	0.02	0.17	0.50
1.30	0.14	28.48	0.00	0.00	0.08	0.23	0.58
1.40	0.17	28.54	0.00	0.00	0.13	0.28	0.63
1.50	0.21	28.60	0.00	0.02	0.18	0.34	0.70
1.60	0.26	28.66	0.00	0.07	0.23	0.39	0.77
1.70	0.30	28.72	0.00	0.12	0.28	0.45	0.83
1.80	0.35	28.78	0.00	0.16	0.33	0.50	0.90
1.90	0.40	28.84	0.00	0.21	0.38	0.56	0.96
2.00	0.44	28.91	0.00	0.26	0.44	0.61	1.00

Table 66: Call option prices for April Nino 3.4 SST conditioned on IRI ensemble forecasts released in January

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	26.61	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	26.66	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	26.72	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	26.77	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	26.82	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	26.87	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	26.93	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	26.98	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	27.03	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	27.08	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	27.14	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	27.19	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	27.24	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	27.29	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	27.35	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	27.40	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	27.45	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	27.50	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	27.56	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	27.61	0.00	0.00	0.00	0.00	0.00
0.00	0.00	27.66	0.00	0.00	0.00	0.00	0.00
0.10	0.00	27.71	0.00	0.00	0.00	0.00	0.00
0.20	0.00	27.77	0.00	0.00	0.00	0.00	0.00
0.30	0.00	27.82	0.00	0.00	0.00	0.00	0.00
0.40	0.00	27.87	0.00	0.00	0.00	0.00	0.02
0.50	0.01	27.93	0.00	0.00	0.00	0.00	0.07
0.60	0.01	27.98	0.00	0.00	0.00	0.00	0.11
0.70	0.01	28.03	0.00	0.00	0.00	0.00	0.17
0.80	0.02	28.08	0.00	0.00	0.00	0.00	0.22
0.90	0.02	28.14	0.00	0.00	0.00	0.00	0.28
1.00	0.03	28.19	0.00	0.00	0.00	0.00	0.33
1.10	0.05	28.24	0.00	0.00	0.00	0.03	0.38
1.20	0.06	28.29	0.00	0.00	0.00	0.08	0.44
1.30	0.08	28.35	0.00	0.00	0.00	0.12	0.49
1.40	0.11	28.40	0.00	0.00	0.01	0.17	0.54
1.50	0.13	28.45	0.00	0.00	0.05	0.22	0.60
1.60	0.16	28.51	0.00	0.00	0.10	0.27	0.66
1.70	0.20	28.56	0.00	0.00	0.14	0.32	0.71
1.80	0.23	28.61	0.00	0.01	0.19	0.37	0.77
1.90	0.27	28.66	0.00	0.05	0.23	0.42	0.84
2.00	0.30	28.72	0.00	0.09	0.27	0.46	0.89

Table 67: Call option prices for April Nino 3.4 SST conditioned on IRI ensemble forecasts released in December

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	26.64	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	26.69	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	26.74	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	26.79	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	26.84	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	26.89	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	26.94	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	26.98	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	27.04	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	27.08	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	27.14	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	27.18	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	27.23	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	27.28	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	27.34	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	27.38	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	27.44	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	27.48	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	27.53	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	27.58	0.00	0.00	0.00	0.00	0.00
0.00	0.00	27.63	0.00	0.00	0.00	0.00	0.00
0.10	0.00	27.68	0.00	0.00	0.00	0.00	0.00
0.20	0.00	27.73	0.00	0.00	0.00	0.00	0.00
0.30	0.00	27.78	0.00	0.00	0.00	0.00	0.00
0.40	0.01	27.83	0.00	0.00	0.00	0.00	0.05
0.50	0.01	27.88	0.00	0.00	0.00	0.00	0.10
0.60	0.01	27.93	0.00	0.00	0.00	0.00	0.15
0.70	0.01	27.98	0.00	0.00	0.00	0.00	0.19
0.80	0.02	28.03	0.00	0.00	0.00	0.00	0.25
0.90	0.03	28.08	0.00	0.00	0.00	0.00	0.30
1.00	0.03	28.13	0.00	0.00	0.00	0.00	0.35
1.10	0.04	28.18	0.00	0.00	0.00	0.00	0.39
1.20	0.06	28.23	0.00	0.00	0.00	0.05	0.46
1.30	0.07	28.28	0.00	0.00	0.00	0.09	0.50
1.40	0.09	28.33	0.00	0.00	0.00	0.14	0.55
1.50	0.11	28.38	0.00	0.00	0.00	0.18	0.61
1.60	0.14	28.43	0.00	0.00	0.03	0.23	0.67
1.70	0.16	28.48	0.00	0.00	0.07	0.27	0.73
1.80	0.19	28.53	0.00	0.00	0.12	0.32	0.78
1.90	0.22	28.58	0.00	0.00	0.16	0.37	0.84
2.00	0.26	28.63	0.00	0.00	0.20	0.42	0.90

Table 68: Call option prices for April Nino 3.4 SST conditioned on IRI ensemble forecasts released in November

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	26.60	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	26.65	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	26.70	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	26.75	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	26.80	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	26.85	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	26.90	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	26.95	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	27.00	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	27.05	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	27.10	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	27.15	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	27.20	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	27.26	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	27.30	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	27.35	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	27.41	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	27.45	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	27.50	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	27.56	0.00	0.00	0.00	0.00	0.00
0.00	0.00	27.61	0.00	0.00	0.00	0.00	0.00
0.10	0.00	27.66	0.00	0.00	0.00	0.00	0.00
0.20	0.00	27.71	0.00	0.00	0.00	0.00	0.00
0.30	0.01	27.76	0.00	0.00	0.00	0.00	0.04
0.40	0.01	27.81	0.00	0.00	0.00	0.00	0.09
0.50	0.01	27.86	0.00	0.00	0.00	0.00	0.14
0.60	0.01	27.91	0.00	0.00	0.00	0.00	0.19
0.70	0.02	27.96	0.00	0.00	0.00	0.00	0.23
0.80	0.02	28.01	0.00	0.00	0.00	0.00	0.28
0.90	0.03	28.05	0.00	0.00	0.00	0.00	0.33
1.00	0.04	28.11	0.00	0.00	0.00	0.00	0.40
1.10	0.05	28.16	0.00	0.00	0.00	0.00	0.44
1.20	0.06	28.21	0.00	0.00	0.00	0.05	0.50
1.30	0.08	28.26	0.00	0.00	0.00	0.09	0.56
1.40	0.10	28.31	0.00	0.00	0.00	0.14	0.61
1.50	0.12	28.36	0.00	0.00	0.00	0.19	0.68
1.60	0.14	28.41	0.00	0.00	0.02	0.24	0.73
1.70	0.17	28.46	0.00	0.00	0.06	0.29	0.80
1.80	0.20	28.51	0.00	0.00	0.10	0.33	0.85
1.90	0.23	28.56	0.00	0.00	0.15	0.38	0.91
2.00	0.26	28.61	0.00	0.00	0.19	0.43	0.98

Table 69: Call option prices for April Nino 3.4 SST conditioned on IRI ensemble forecasts released in October

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	26.52	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	26.57	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	26.62	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	26.68	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	26.73	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	26.79	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	26.84	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	26.89	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	26.95	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	27.00	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	27.06	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	27.11	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	27.16	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	27.22	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	27.27	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	27.33	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	27.38	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	27.43	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	27.49	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	27.54	0.00	0.00	0.00	0.00	0.00
0.00	0.00	27.59	0.00	0.00	0.00	0.00	0.00
0.10	0.00	27.65	0.00	0.00	0.00	0.00	0.00
0.20	0.00	27.70	0.00	0.00	0.00	0.00	0.00
0.30	0.01	27.75	0.00	0.00	0.00	0.00	0.05
0.40	0.01	27.81	0.00	0.00	0.00	0.00	0.10
0.50	0.01	27.86	0.00	0.00	0.00	0.00	0.16
0.60	0.01	27.92	0.00	0.00	0.00	0.00	0.21
0.70	0.02	27.97	0.00	0.00	0.00	0.00	0.26
0.80	0.03	28.02	0.00	0.00	0.00	0.00	0.32
0.90	0.04	28.08	0.00	0.00	0.00	0.00	0.39
1.00	0.05	28.13	0.00	0.00	0.00	0.00	0.44
1.10	0.06	28.18	0.00	0.00	0.00	0.03	0.50
1.20	0.08	28.24	0.00	0.00	0.00	0.08	0.56
1.30	0.10	28.29	0.00	0.00	0.00	0.14	0.62
1.40	0.12	28.35	0.00	0.00	0.00	0.19	0.69
1.50	0.15	28.40	0.00	0.00	0.01	0.24	0.76
1.60	0.17	28.46	0.00	0.00	0.06	0.29	0.82
1.70	0.20	28.51	0.00	0.00	0.10	0.34	0.88
1.80	0.24	28.56	0.00	0.00	0.15	0.39	0.96
1.90	0.27	28.62	0.00	0.00	0.19	0.45	1.00
2.00	0.30	28.67	0.00	0.00	0.24	0.50	1.00

Table 70: Call option prices for April Nino 3.4 SST conditioned on IRI ensemble forecasts released in September

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	26.24	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	26.31	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	26.37	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	26.44	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	26.50	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	26.57	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	26.63	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	26.70	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	26.77	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	26.83	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	26.89	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	26.96	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	27.03	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	27.09	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	27.16	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	27.23	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	27.29	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	27.36	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	27.42	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	27.49	0.00	0.00	0.00	0.00	0.00
0.00	0.00	27.55	0.00	0.00	0.00	0.00	0.00
0.10	0.00	27.62	0.00	0.00	0.00	0.00	0.00
0.20	0.00	27.69	0.00	0.00	0.00	0.00	0.01
0.30	0.01	27.75	0.00	0.00	0.00	0.00	0.06
0.40	0.01	27.82	0.00	0.00	0.00	0.00	0.12
0.50	0.01	27.89	0.00	0.00	0.00	0.00	0.19
0.60	0.02	27.95	0.00	0.00	0.00	0.00	0.25
0.70	0.03	28.02	0.00	0.00	0.00	0.00	0.32
0.80	0.04	28.08	0.00	0.00	0.00	0.00	0.39
0.90	0.05	28.15	0.00	0.00	0.00	0.00	0.47
1.00	0.07	28.21	0.00	0.00	0.00	0.06	0.54
1.10	0.09	28.28	0.00	0.00	0.00	0.12	0.61
1.20	0.12	28.35	0.00	0.00	0.00	0.19	0.70
1.30	0.15	28.41	0.00	0.00	0.02	0.25	0.78
1.40	0.19	28.48	0.00	0.00	0.08	0.32	0.86
1.50	0.23	28.54	0.00	0.00	0.13	0.38	0.94
1.60	0.27	28.61	0.00	0.00	0.19	0.45	1.00
1.70	0.31	28.67	0.00	0.00	0.24	0.51	1.00
1.80	0.35	28.74	0.00	0.02	0.30	0.57	1.00
1.90	0.39	28.81	0.00	0.07	0.35	0.64	1.00
2.00	0.43	28.87	0.00	0.12	0.41	0.71	1.00

Table 71: Call option prices for April Nino 3.4 SST conditioned on IRI ensemble forecasts released in August

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	26.13	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	26.21	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	26.28	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	26.35	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	26.42	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	26.49	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	26.56	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	26.63	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	26.70	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	26.77	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	26.84	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	26.91	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	26.98	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	27.05	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	27.12	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	27.19	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	27.26	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	27.33	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	27.40	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	27.47	0.00	0.00	0.00	0.00	0.00
0.00	0.00	27.54	0.00	0.00	0.00	0.00	0.00
0.10	0.00	27.61	0.00	0.00	0.00	0.00	0.00
0.20	0.00	27.68	0.00	0.00	0.00	0.00	0.02
0.30	0.01	27.75	0.00	0.00	0.00	0.00	0.08
0.40	0.01	27.82	0.00	0.00	0.00	0.00	0.15
0.50	0.01	27.89	0.00	0.00	0.00	0.00	0.22
0.60	0.02	27.96	0.00	0.00	0.00	0.00	0.28
0.70	0.03	28.03	0.00	0.00	0.00	0.00	0.37
0.80	0.05	28.11	0.00	0.00	0.00	0.00	0.45
0.90	0.06	28.17	0.00	0.00	0.00	0.03	0.52
1.00	0.09	28.24	0.00	0.00	0.00	0.10	0.61
1.10	0.11	28.31	0.00	0.00	0.00	0.16	0.69
1.20	0.14	28.38	0.00	0.00	0.00	0.23	0.77
1.30	0.18	28.45	0.00	0.00	0.05	0.30	0.88
1.40	0.22	28.52	0.00	0.00	0.11	0.37	0.97
1.50	0.26	28.59	0.00	0.00	0.17	0.44	1.00
1.60	0.30	28.66	0.00	0.00	0.23	0.51	1.00
1.70	0.35	28.73	0.00	0.00	0.29	0.58	1.00
1.80	0.39	28.80	0.00	0.05	0.35	0.65	1.00
1.90	0.44	28.87	0.00	0.10	0.41	0.72	1.00
2.00	0.48	28.94	0.00	0.14	0.47	0.79	1.00

Table 72: Call option prices for April Nino 3.4 SST conditioned on IRI ensemble forecasts released in July

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	26.05	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	26.12	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	26.20	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	26.28	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	26.35	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	26.42	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	26.49	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	26.57	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	26.64	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	26.72	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	26.79	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	26.86	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	26.94	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	27.01	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	27.08	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	27.16	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	27.23	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	27.31	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	27.38	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	27.45	0.00	0.00	0.00	0.00	0.00
0.00	0.00	27.52	0.00	0.00	0.00	0.00	0.00
0.10	0.01	27.60	0.00	0.00	0.00	0.00	0.01
0.20	0.01	27.68	0.00	0.00	0.00	0.00	0.08
0.30	0.01	27.75	0.00	0.00	0.00	0.00	0.14
0.40	0.02	27.82	0.00	0.00	0.00	0.00	0.23
0.50	0.02	27.90	0.00	0.00	0.00	0.00	0.30
0.60	0.03	27.97	0.00	0.00	0.00	0.00	0.37
0.70	0.04	28.04	0.00	0.00	0.00	0.00	0.46
0.80	0.06	28.12	0.00	0.00	0.00	0.00	0.55
0.90	0.08	28.19	0.00	0.00	0.00	0.08	0.64
1.00	0.11	28.26	0.00	0.00	0.00	0.14	0.74
1.10	0.14	28.34	0.00	0.00	0.00	0.22	0.84
1.20	0.18	28.41	0.00	0.00	0.02	0.30	0.94
1.30	0.22	28.48	0.00	0.00	0.08	0.37	1.00
1.40	0.26	28.56	0.00	0.00	0.15	0.45	1.00
1.50	0.30	28.63	0.00	0.00	0.21	0.52	1.00
1.60	0.35	28.71	0.00	0.00	0.27	0.60	1.00
1.70	0.39	28.78	0.00	0.00	0.33	0.68	1.00
1.80	0.43	28.86	0.00	0.03	0.39	0.75	1.00
1.90	0.47	28.93	0.00	0.08	0.46	0.83	1.00
2.00	0.51	29.00	0.00	0.12	0.52	0.91	1.00

Table 73: Call option prices for April Nino 3.4 SST conditioned on IRI ensemble forecasts released in June

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	26.37	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	26.43	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	26.50	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	26.55	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	26.62	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	26.68	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	26.74	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	26.80	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	26.86	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	26.92	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	26.98	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	27.04	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	27.10	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	27.16	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	27.22	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	27.28	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	27.34	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	27.40	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	27.46	0.00	0.00	0.00	0.00	0.00
-0.10	0.01	27.52	0.00	0.00	0.00	0.00	0.00
0.00	0.01	27.58	0.00	0.00	0.00	0.00	0.03
0.10	0.01	27.64	0.00	0.00	0.00	0.00	0.10
0.20	0.01	27.70	0.00	0.00	0.00	0.00	0.14
0.30	0.01	27.76	0.00	0.00	0.00	0.00	0.19
0.40	0.02	27.82	0.00	0.00	0.00	0.00	0.24
0.50	0.02	27.88	0.00	0.00	0.00	0.00	0.31
0.60	0.03	27.95	0.00	0.00	0.00	0.00	0.39
0.70	0.04	28.00	0.00	0.00	0.00	0.00	0.47
0.80	0.06	28.07	0.00	0.00	0.00	0.00	0.54
0.90	0.07	28.13	0.00	0.00	0.00	0.03	0.61
1.00	0.09	28.19	0.00	0.00	0.00	0.09	0.70
1.10	0.12	28.25	0.00	0.00	0.00	0.15	0.78
1.20	0.14	28.31	0.00	0.00	0.00	0.22	0.87
1.30	0.17	28.37	0.00	0.00	0.00	0.28	0.95
1.40	0.20	28.43	0.00	0.00	0.03	0.34	1.00
1.50	0.24	28.49	0.00	0.00	0.09	0.41	1.00
1.60	0.27	28.55	0.00	0.00	0.14	0.47	1.00
1.70	0.30	28.61	0.00	0.00	0.19	0.54	1.00
1.80	0.34	28.67	0.00	0.00	0.24	0.61	1.00
1.90	0.37	28.73	0.00	0.00	0.30	0.67	1.00
2.00	0.41	28.79	0.00	0.00	0.34	0.74	1.00

Table 74: Put option prices for April Nino 3.4 SST conditioned on IRI ensemble forecasts released in February

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.61	26.47	0.04	0.44	0.62	0.80	1.00
-1.90	0.56	26.53	0.00	0.40	0.57	0.74	1.00
-1.80	0.52	26.59	0.00	0.35	0.52	0.69	1.00
-1.70	0.47	26.65	0.00	0.30	0.46	0.63	1.00
-1.60	0.42	26.71	0.00	0.25	0.41	0.57	0.95
-1.50	0.37	26.77	0.00	0.21	0.36	0.52	0.87
-1.40	0.32	26.83	0.00	0.16	0.31	0.46	0.81
-1.30	0.28	26.89	0.00	0.11	0.26	0.41	0.75
-1.20	0.23	26.95	0.00	0.07	0.21	0.36	0.69
-1.10	0.19	27.01	0.00	0.02	0.16	0.30	0.63
-1.00	0.15	27.08	0.00	0.00	0.10	0.24	0.57
-0.90	0.11	27.14	0.00	0.00	0.05	0.19	0.50
-0.80	0.08	27.20	0.00	0.00	0.00	0.13	0.45
-0.70	0.06	27.26	0.00	0.00	0.00	0.08	0.38
-0.60	0.04	27.32	0.00	0.00	0.00	0.02	0.32
-0.50	0.03	27.38	0.00	0.00	0.00	0.00	0.27
-0.40	0.02	27.44	0.00	0.00	0.00	0.00	0.21
-0.30	0.01	27.50	0.00	0.00	0.00	0.00	0.16
-0.20	0.01	27.57	0.00	0.00	0.00	0.00	0.10
-0.10	0.00	27.63	0.00	0.00	0.00	0.00	0.05
0.00	0.00	27.69	0.00	0.00	0.00	0.00	0.00
0.10	0.00	27.75	0.00	0.00	0.00	0.00	0.00
0.20	0.00	27.81	0.00	0.00	0.00	0.00	0.00
0.30	0.00	27.87	0.00	0.00	0.00	0.00	0.00
0.40	0.00	27.93	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.99	0.00	0.00	0.00	0.00	0.00
0.60	0.00	28.05	0.00	0.00	0.00	0.00	0.00
0.70	0.00	28.11	0.00	0.00	0.00	0.00	0.00
0.80	0.00	28.17	0.00	0.00	0.00	0.00	0.00
0.90	0.00	28.24	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.30	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.36	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.42	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.48	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.54	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.60	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.66	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.72	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.78	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.84	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.91	0.00	0.00	0.00	0.00	0.00

Table 75: Put option prices for April Nino 3.4 SST conditioned on IRI ensemble forecasts released in January

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.50	26.61	0.00	0.31	0.50	0.69	1.00
-1.90	0.46	26.66	0.00	0.28	0.46	0.64	1.00
-1.80	0.42	26.72	0.00	0.23	0.41	0.59	0.99
-1.70	0.38	26.77	0.00	0.19	0.37	0.54	0.93
-1.60	0.34	26.82	0.00	0.15	0.32	0.50	0.88
-1.50	0.30	26.87	0.00	0.11	0.28	0.45	0.83
-1.40	0.26	26.93	0.00	0.07	0.23	0.40	0.76
-1.30	0.22	26.98	0.00	0.03	0.19	0.35	0.71
-1.20	0.19	27.03	0.00	0.00	0.14	0.30	0.65
-1.10	0.15	27.08	0.00	0.00	0.10	0.25	0.60
-1.00	0.12	27.14	0.00	0.00	0.06	0.21	0.55
-0.90	0.10	27.19	0.00	0.00	0.01	0.16	0.50
-0.80	0.08	27.24	0.00	0.00	0.00	0.11	0.44
-0.70	0.06	27.29	0.00	0.00	0.00	0.07	0.39
-0.60	0.04	27.35	0.00	0.00	0.00	0.02	0.34
-0.50	0.03	27.40	0.00	0.00	0.00	0.00	0.29
-0.40	0.02	27.45	0.00	0.00	0.00	0.00	0.24
-0.30	0.01	27.50	0.00	0.00	0.00	0.00	0.19
-0.20	0.01	27.56	0.00	0.00	0.00	0.00	0.15
-0.10	0.01	27.61	0.00	0.00	0.00	0.00	0.10
0.00	0.01	27.66	0.00	0.00	0.00	0.00	0.06
0.10	0.00	27.71	0.00	0.00	0.00	0.00	0.01
0.20	0.00	27.77	0.00	0.00	0.00	0.00	0.00
0.30	0.00	27.82	0.00	0.00	0.00	0.00	0.00
0.40	0.00	27.87	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.93	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.98	0.00	0.00	0.00	0.00	0.00
0.70	0.00	28.03	0.00	0.00	0.00	0.00	0.00
0.80	0.00	28.08	0.00	0.00	0.00	0.00	0.00
0.90	0.00	28.14	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.19	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.24	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.29	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.35	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.40	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.45	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.51	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.56	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.61	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.66	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.72	0.00	0.00	0.00	0.00	0.00

Table 76: Put option prices for April Nino 3.4 SST conditioned on IRI ensemble forecasts released in December

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.48	26.64	0.00	0.26	0.48	0.70	1.00
-1.90	0.44	26.69	0.00	0.22	0.43	0.65	1.00
-1.80	0.41	26.74	0.00	0.18	0.39	0.60	1.00
-1.70	0.37	26.79	0.00	0.14	0.35	0.56	1.00
-1.60	0.33	26.84	0.00	0.11	0.31	0.51	0.97
-1.50	0.30	26.89	0.00	0.07	0.27	0.46	0.90
-1.40	0.26	26.94	0.00	0.03	0.22	0.42	0.85
-1.30	0.23	26.98	0.00	0.00	0.18	0.37	0.79
-1.20	0.20	27.04	0.00	0.00	0.14	0.33	0.74
-1.10	0.17	27.08	0.00	0.00	0.10	0.28	0.69
-1.00	0.14	27.14	0.00	0.00	0.06	0.23	0.63
-0.90	0.12	27.18	0.00	0.00	0.01	0.19	0.58
-0.80	0.09	27.23	0.00	0.00	0.00	0.14	0.53
-0.70	0.07	27.28	0.00	0.00	0.00	0.10	0.48
-0.60	0.06	27.34	0.00	0.00	0.00	0.05	0.43
-0.50	0.04	27.38	0.00	0.00	0.00	0.01	0.38
-0.40	0.03	27.44	0.00	0.00	0.00	0.00	0.33
-0.30	0.02	27.48	0.00	0.00	0.00	0.00	0.28
-0.20	0.02	27.53	0.00	0.00	0.00	0.00	0.24
-0.10	0.01	27.58	0.00	0.00	0.00	0.00	0.20
0.00	0.01	27.63	0.00	0.00	0.00	0.00	0.16
0.10	0.01	27.68	0.00	0.00	0.00	0.00	0.11
0.20	0.01	27.73	0.00	0.00	0.00	0.00	0.06
0.30	0.00	27.78	0.00	0.00	0.00	0.00	0.03
0.40	0.00	27.83	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.88	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.93	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.98	0.00	0.00	0.00	0.00	0.00
0.80	0.00	28.03	0.00	0.00	0.00	0.00	0.00
0.90	0.00	28.08	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.13	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.18	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.23	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.28	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.33	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.38	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.43	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.48	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.53	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.58	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.63	0.00	0.00	0.00	0.00	0.00

Table 77: Put option prices for April Nino 3.4 SST conditioned on IRI ensemble forecasts released in November

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.51	26.60	0.00	0.25	0.51	0.77	1.00
-1.90	0.47	26.65	0.00	0.22	0.47	0.72	1.00
-1.80	0.44	26.70	0.00	0.18	0.43	0.67	1.00
-1.70	0.40	26.75	0.00	0.14	0.38	0.62	1.00
-1.60	0.37	26.80	0.00	0.11	0.34	0.57	1.00
-1.50	0.33	26.85	0.00	0.07	0.29	0.52	1.00
-1.40	0.30	26.90	0.00	0.03	0.26	0.48	0.97
-1.30	0.26	26.95	0.00	0.00	0.21	0.43	0.90
-1.20	0.23	27.00	0.00	0.00	0.17	0.38	0.85
-1.10	0.20	27.05	0.00	0.00	0.13	0.33	0.78
-1.00	0.17	27.10	0.00	0.00	0.08	0.28	0.73
-0.90	0.14	27.15	0.00	0.00	0.04	0.24	0.67
-0.80	0.12	27.20	0.00	0.00	0.00	0.19	0.62
-0.70	0.10	27.26	0.00	0.00	0.00	0.14	0.56
-0.60	0.08	27.30	0.00	0.00	0.00	0.10	0.52
-0.50	0.06	27.35	0.00	0.00	0.00	0.06	0.46
-0.40	0.05	27.41	0.00	0.00	0.00	0.01	0.41
-0.30	0.04	27.45	0.00	0.00	0.00	0.00	0.36
-0.20	0.03	27.50	0.00	0.00	0.00	0.00	0.32
-0.10	0.02	27.56	0.00	0.00	0.00	0.00	0.28
0.00	0.02	27.61	0.00	0.00	0.00	0.00	0.23
0.10	0.01	27.66	0.00	0.00	0.00	0.00	0.18
0.20	0.01	27.71	0.00	0.00	0.00	0.00	0.14
0.30	0.01	27.76	0.00	0.00	0.00	0.00	0.10
0.40	0.01	27.81	0.00	0.00	0.00	0.00	0.06
0.50	0.00	27.86	0.00	0.00	0.00	0.00	0.02
0.60	0.00	27.91	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.96	0.00	0.00	0.00	0.00	0.00
0.80	0.00	28.01	0.00	0.00	0.00	0.00	0.00
0.90	0.00	28.05	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.11	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.16	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.21	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.26	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.31	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.36	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.41	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.46	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.51	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.56	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.61	0.00	0.00	0.00	0.00	0.00

Table 78: Put option prices for April Nino 3.4 SST conditioned on IRI ensemble forecasts released in October

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.56	26.52	0.00	0.30	0.57	0.86	1.00
-1.90	0.52	26.57	0.00	0.26	0.53	0.80	1.00
-1.80	0.49	26.62	0.00	0.22	0.49	0.75	1.00
-1.70	0.45	26.68	0.00	0.18	0.44	0.70	1.00
-1.60	0.42	26.73	0.00	0.14	0.40	0.65	1.00
-1.50	0.38	26.79	0.00	0.11	0.35	0.59	1.00
-1.40	0.34	26.84	0.00	0.07	0.31	0.55	1.00
-1.30	0.31	26.89	0.00	0.03	0.26	0.49	1.00
-1.20	0.27	26.95	0.00	0.00	0.21	0.44	0.93
-1.10	0.23	27.00	0.00	0.00	0.17	0.39	0.87
-1.00	0.20	27.06	0.00	0.00	0.12	0.33	0.82
-0.90	0.17	27.11	0.00	0.00	0.08	0.29	0.75
-0.80	0.14	27.16	0.00	0.00	0.03	0.24	0.70
-0.70	0.12	27.22	0.00	0.00	0.00	0.18	0.63
-0.60	0.09	27.27	0.00	0.00	0.00	0.14	0.57
-0.50	0.07	27.33	0.00	0.00	0.00	0.09	0.52
-0.40	0.06	27.38	0.00	0.00	0.00	0.04	0.47
-0.30	0.04	27.43	0.00	0.00	0.00	0.00	0.40
-0.20	0.03	27.49	0.00	0.00	0.00	0.00	0.35
-0.10	0.03	27.54	0.00	0.00	0.00	0.00	0.30
0.00	0.02	27.59	0.00	0.00	0.00	0.00	0.26
0.10	0.01	27.65	0.00	0.00	0.00	0.00	0.21
0.20	0.01	27.70	0.00	0.00	0.00	0.00	0.16
0.30	0.01	27.75	0.00	0.00	0.00	0.00	0.12
0.40	0.01	27.81	0.00	0.00	0.00	0.00	0.07
0.50	0.01	27.86	0.00	0.00	0.00	0.00	0.03
0.60	0.00	27.92	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.97	0.00	0.00	0.00	0.00	0.00
0.80	0.00	28.02	0.00	0.00	0.00	0.00	0.00
0.90	0.00	28.08	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.13	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.18	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.24	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.29	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.35	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.40	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.46	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.51	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.56	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.62	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.67	0.00	0.00	0.00	0.00	0.00

Table 79: Put option prices for April Nino 3.4 SST conditioned on IRI ensemble forecasts released in September

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.71	26.24	0.00	0.49	0.82	1.00	1.00
-1.90	0.68	26.31	0.00	0.44	0.76	1.00	1.00
-1.80	0.64	26.37	0.00	0.40	0.71	1.00	1.00
-1.70	0.61	26.44	0.00	0.35	0.65	0.95	1.00
-1.60	0.57	26.50	0.00	0.31	0.60	0.88	1.00
-1.50	0.53	26.57	0.00	0.26	0.54	0.82	1.00
-1.40	0.49	26.63	0.00	0.21	0.49	0.75	1.00
-1.30	0.44	26.70	0.00	0.17	0.43	0.69	1.00
-1.20	0.40	26.77	0.00	0.12	0.37	0.62	1.00
-1.10	0.35	26.83	0.00	0.07	0.31	0.55	1.00
-1.00	0.31	26.89	0.00	0.03	0.26	0.50	1.00
-0.90	0.26	26.96	0.00	0.00	0.20	0.43	0.93
-0.80	0.22	27.03	0.00	0.00	0.15	0.37	0.85
-0.70	0.18	27.09	0.00	0.00	0.09	0.30	0.77
-0.60	0.15	27.16	0.00	0.00	0.04	0.24	0.70
-0.50	0.11	27.23	0.00	0.00	0.00	0.18	0.62
-0.40	0.09	27.29	0.00	0.00	0.00	0.12	0.55
-0.30	0.06	27.36	0.00	0.00	0.00	0.06	0.48
-0.20	0.05	27.42	0.00	0.00	0.00	0.00	0.41
-0.10	0.03	27.49	0.00	0.00	0.00	0.00	0.36
0.00	0.02	27.55	0.00	0.00	0.00	0.00	0.29
0.10	0.02	27.62	0.00	0.00	0.00	0.00	0.23
0.20	0.01	27.69	0.00	0.00	0.00	0.00	0.17
0.30	0.01	27.75	0.00	0.00	0.00	0.00	0.13
0.40	0.01	27.82	0.00	0.00	0.00	0.00	0.08
0.50	0.00	27.89	0.00	0.00	0.00	0.00	0.03
0.60	0.00	27.95	0.00	0.00	0.00	0.00	0.00
0.70	0.00	28.02	0.00	0.00	0.00	0.00	0.00
0.80	0.00	28.08	0.00	0.00	0.00	0.00	0.00
0.90	0.00	28.15	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.21	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.28	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.35	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.41	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.48	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.54	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.61	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.67	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.74	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.81	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.87	0.00	0.00	0.00	0.00	0.00

Table 80: Put option prices for April Nino 3.4 SST conditioned on IRI ensemble forecasts released in August

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.74	26.13	0.00	0.54	0.90	1.00	1.00
-1.90	0.71	26.21	0.00	0.49	0.84	1.00	1.00
-1.80	0.68	26.28	0.00	0.44	0.78	1.00	1.00
-1.70	0.65	26.35	0.00	0.40	0.73	1.00	1.00
-1.60	0.62	26.42	0.00	0.35	0.67	0.98	1.00
-1.50	0.58	26.49	0.00	0.30	0.61	0.91	1.00
-1.40	0.53	26.56	0.00	0.25	0.55	0.84	1.00
-1.30	0.49	26.63	0.00	0.20	0.49	0.77	1.00
-1.20	0.44	26.70	0.00	0.15	0.43	0.70	1.00
-1.10	0.40	26.77	0.00	0.11	0.37	0.63	1.00
-1.00	0.35	26.84	0.00	0.06	0.31	0.56	1.00
-0.90	0.30	26.91	0.00	0.00	0.25	0.49	1.00
-0.80	0.26	26.98	0.00	0.00	0.19	0.42	0.95
-0.70	0.21	27.05	0.00	0.00	0.13	0.36	0.86
-0.60	0.17	27.12	0.00	0.00	0.07	0.29	0.78
-0.50	0.14	27.19	0.00	0.00	0.01	0.22	0.69
-0.40	0.10	27.26	0.00	0.00	0.00	0.16	0.62
-0.30	0.08	27.33	0.00	0.00	0.00	0.09	0.54
-0.20	0.06	27.40	0.00	0.00	0.00	0.03	0.47
-0.10	0.04	27.47	0.00	0.00	0.00	0.00	0.40
0.00	0.03	27.54	0.00	0.00	0.00	0.00	0.33
0.10	0.02	27.61	0.00	0.00	0.00	0.00	0.27
0.20	0.01	27.68	0.00	0.00	0.00	0.00	0.21
0.30	0.01	27.75	0.00	0.00	0.00	0.00	0.15
0.40	0.01	27.82	0.00	0.00	0.00	0.00	0.10
0.50	0.01	27.89	0.00	0.00	0.00	0.00	0.05
0.60	0.00	27.96	0.00	0.00	0.00	0.00	0.01
0.70	0.00	28.03	0.00	0.00	0.00	0.00	0.00
0.80	0.00	28.11	0.00	0.00	0.00	0.00	0.00
0.90	0.00	28.17	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.24	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.31	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.38	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.45	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.52	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.59	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.66	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.73	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.80	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.87	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.94	0.00	0.00	0.00	0.00	0.00

Table 81: Put option prices for April Nino 3.4 SST conditioned on IRI ensemble forecasts released in July

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.75	26.05	0.00	0.54	0.98	1.00	1.00
-1.90	0.72	26.12	0.00	0.49	0.92	1.00	1.00
-1.80	0.70	26.20	0.00	0.45	0.86	1.00	1.00
-1.70	0.67	26.28	0.00	0.40	0.79	1.00	1.00
-1.60	0.64	26.35	0.00	0.35	0.73	1.00	1.00
-1.50	0.61	26.42	0.00	0.31	0.66	1.00	1.00
-1.40	0.57	26.49	0.00	0.26	0.60	0.94	1.00
-1.30	0.53	26.57	0.00	0.21	0.54	0.87	1.00
-1.20	0.48	26.64	0.00	0.16	0.48	0.79	1.00
-1.10	0.44	26.72	0.00	0.11	0.41	0.71	1.00
-1.00	0.39	26.79	0.00	0.06	0.35	0.64	1.00
-0.90	0.34	26.86	0.00	0.01	0.29	0.56	1.00
-0.80	0.29	26.94	0.00	0.00	0.23	0.48	1.00
-0.70	0.25	27.01	0.00	0.00	0.16	0.42	0.98
-0.60	0.20	27.08	0.00	0.00	0.10	0.35	0.88
-0.50	0.16	27.16	0.00	0.00	0.04	0.27	0.79
-0.40	0.13	27.23	0.00	0.00	0.00	0.20	0.70
-0.30	0.10	27.31	0.00	0.00	0.00	0.13	0.62
-0.20	0.07	27.38	0.00	0.00	0.00	0.06	0.53
-0.10	0.05	27.45	0.00	0.00	0.00	0.00	0.47
0.00	0.04	27.52	0.00	0.00	0.00	0.00	0.40
0.10	0.03	27.60	0.00	0.00	0.00	0.00	0.33
0.20	0.02	27.68	0.00	0.00	0.00	0.00	0.26
0.30	0.01	27.75	0.00	0.00	0.00	0.00	0.21
0.40	0.01	27.82	0.00	0.00	0.00	0.00	0.16
0.50	0.01	27.90	0.00	0.00	0.00	0.00	0.12
0.60	0.01	27.97	0.00	0.00	0.00	0.00	0.08
0.70	0.01	28.04	0.00	0.00	0.00	0.00	0.04
0.80	0.01	28.12	0.00	0.00	0.00	0.00	0.00
0.90	0.01	28.19	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.26	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.34	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.41	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.48	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.56	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.63	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.71	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.78	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.86	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.93	0.00	0.00	0.00	0.00	0.00
2.00	0.01	29.00	0.00	0.00	0.00	0.00	0.00

Table 82: Put option prices for April Nino 3.4 SST conditioned on IRI ensemble forecasts released in June

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.61	26.37	0.00	0.27	0.70	1.00	1.00
-1.90	0.59	26.43	0.00	0.24	0.65	1.00	1.00
-1.80	0.56	26.50	0.00	0.20	0.60	1.00	1.00
-1.70	0.53	26.55	0.00	0.16	0.55	0.93	1.00
-1.60	0.50	26.62	0.00	0.13	0.50	0.87	1.00
-1.50	0.46	26.68	0.00	0.09	0.45	0.80	1.00
-1.40	0.43	26.74	0.00	0.05	0.39	0.74	1.00
-1.30	0.40	26.80	0.00	0.01	0.35	0.68	1.00
-1.20	0.36	26.86	0.00	0.00	0.29	0.61	1.00
-1.10	0.32	26.92	0.00	0.00	0.24	0.55	1.00
-1.00	0.28	26.98	0.00	0.00	0.19	0.48	1.00
-0.90	0.25	27.04	0.00	0.00	0.14	0.42	1.00
-0.80	0.21	27.10	0.00	0.00	0.09	0.36	0.97
-0.70	0.18	27.16	0.00	0.00	0.03	0.30	0.88
-0.60	0.15	27.22	0.00	0.00	0.00	0.24	0.79
-0.50	0.12	27.28	0.00	0.00	0.00	0.18	0.72
-0.40	0.09	27.34	0.00	0.00	0.00	0.12	0.64
-0.30	0.07	27.40	0.00	0.00	0.00	0.06	0.57
-0.20	0.06	27.46	0.00	0.00	0.00	0.01	0.51
-0.10	0.04	27.52	0.00	0.00	0.00	0.00	0.44
0.00	0.03	27.58	0.00	0.00	0.00	0.00	0.39
0.10	0.03	27.64	0.00	0.00	0.00	0.00	0.33
0.20	0.02	27.70	0.00	0.00	0.00	0.00	0.28
0.30	0.02	27.76	0.00	0.00	0.00	0.00	0.23
0.40	0.01	27.82	0.00	0.00	0.00	0.00	0.20
0.50	0.01	27.88	0.00	0.00	0.00	0.00	0.16
0.60	0.01	27.95	0.00	0.00	0.00	0.00	0.13
0.70	0.01	28.00	0.00	0.00	0.00	0.00	0.09
0.80	0.01	28.07	0.00	0.00	0.00	0.00	0.07
0.90	0.01	28.13	0.00	0.00	0.00	0.00	0.04
1.00	0.01	28.19	0.00	0.00	0.00	0.00	0.03
1.10	0.01	28.25	0.00	0.00	0.00	0.00	0.02
1.20	0.01	28.31	0.00	0.00	0.00	0.00	0.00
1.30	0.01	28.37	0.00	0.00	0.00	0.00	0.00
1.40	0.01	28.43	0.00	0.00	0.00	0.00	0.00
1.50	0.01	28.49	0.00	0.00	0.00	0.00	0.00
1.60	0.01	28.55	0.00	0.00	0.00	0.00	0.00
1.70	0.01	28.61	0.00	0.00	0.00	0.00	0.00
1.80	0.01	28.67	0.00	0.00	0.00	0.00	0.00
1.90	0.01	28.73	0.00	0.00	0.00	0.00	0.00
2.00	0.01	28.79	0.00	0.00	0.00	0.00	0.00

Appendix H: May Pricing

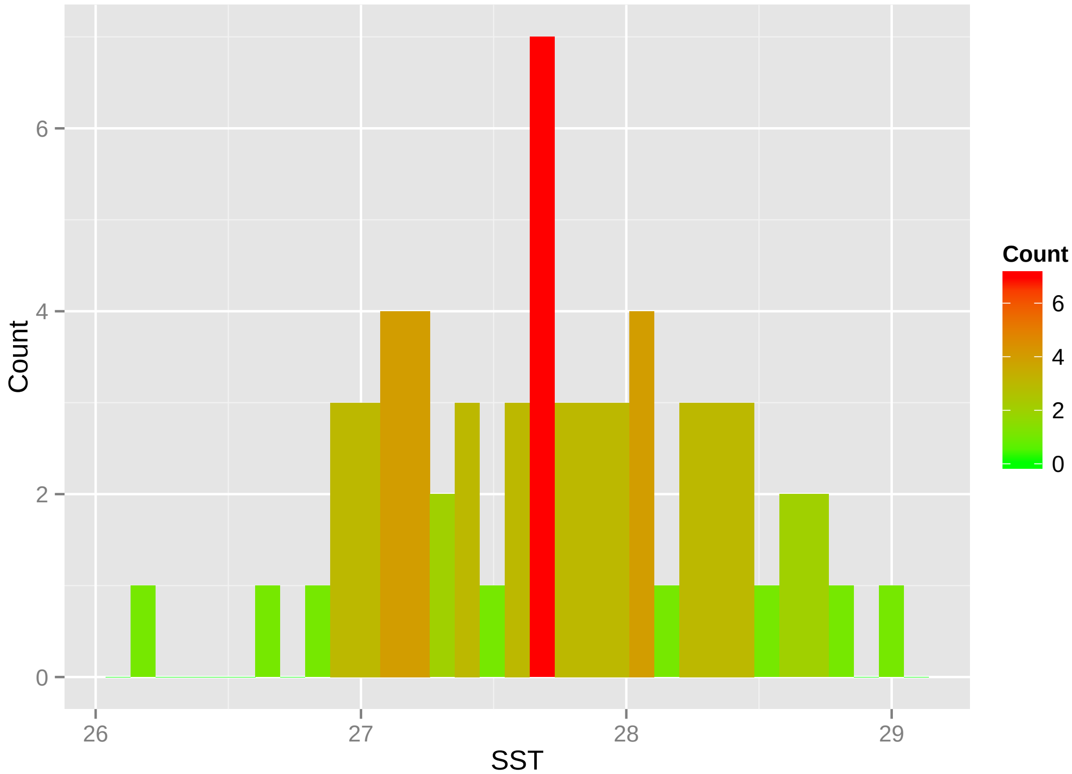


Figure 55: Histogram of May SST for Niño 3.4 ERSST.3b

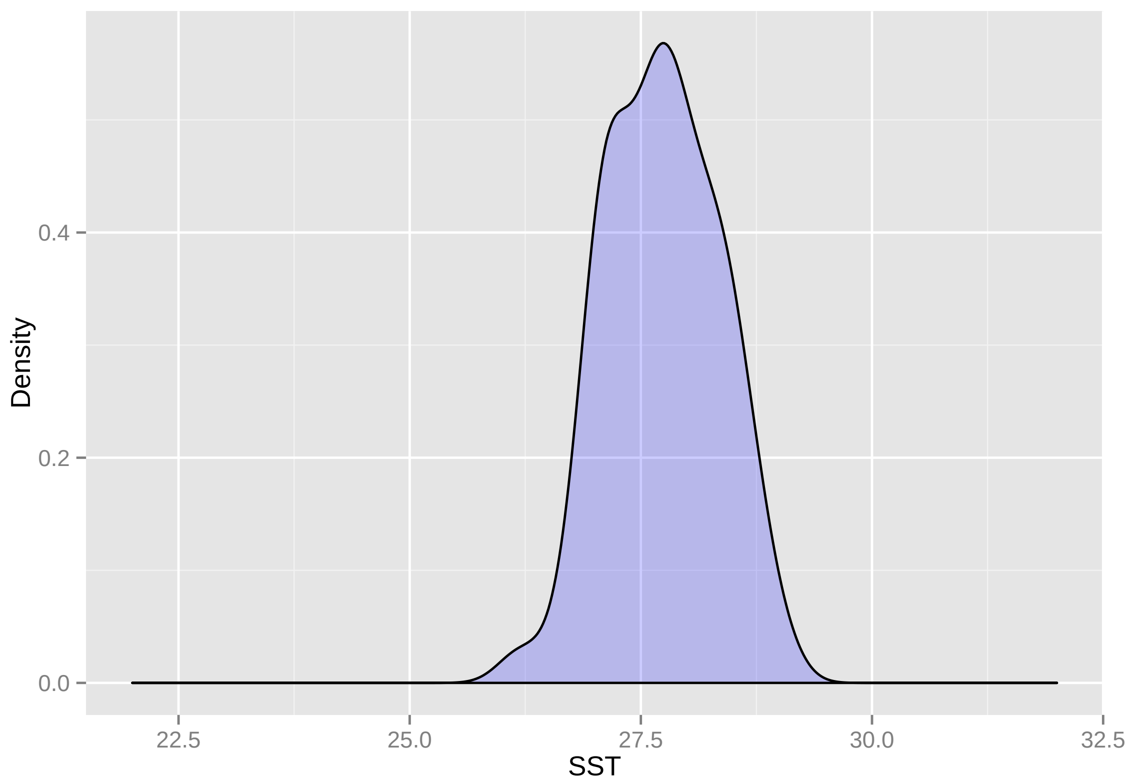


Figure 56: Kernel density estimate of May SST for Niño 3.4 ERSST.3b

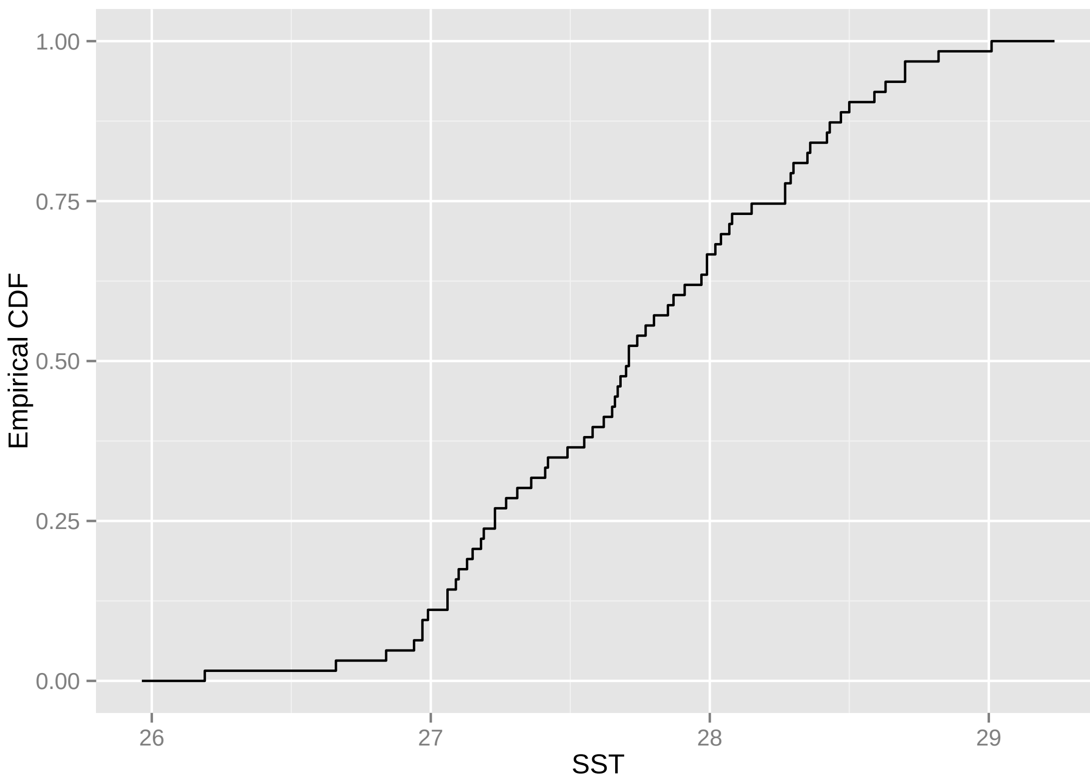


Figure 57: ECDF of May SST for Niño 3.4 ERSST.3b

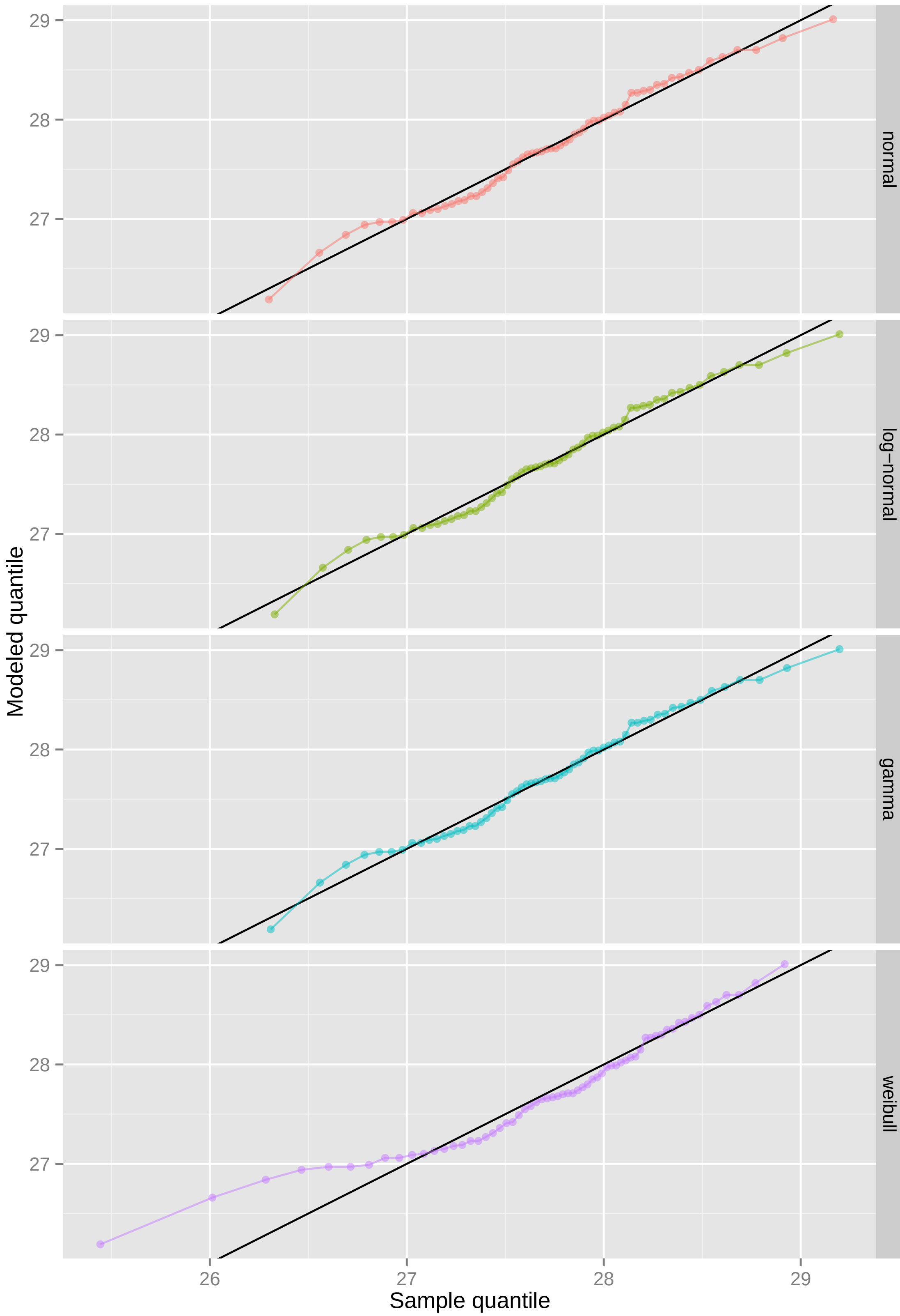


Figure 58: QQ plots of May SST for Niño 3.4 ERSST.3b compared to samples from various distributions (n=2 million)

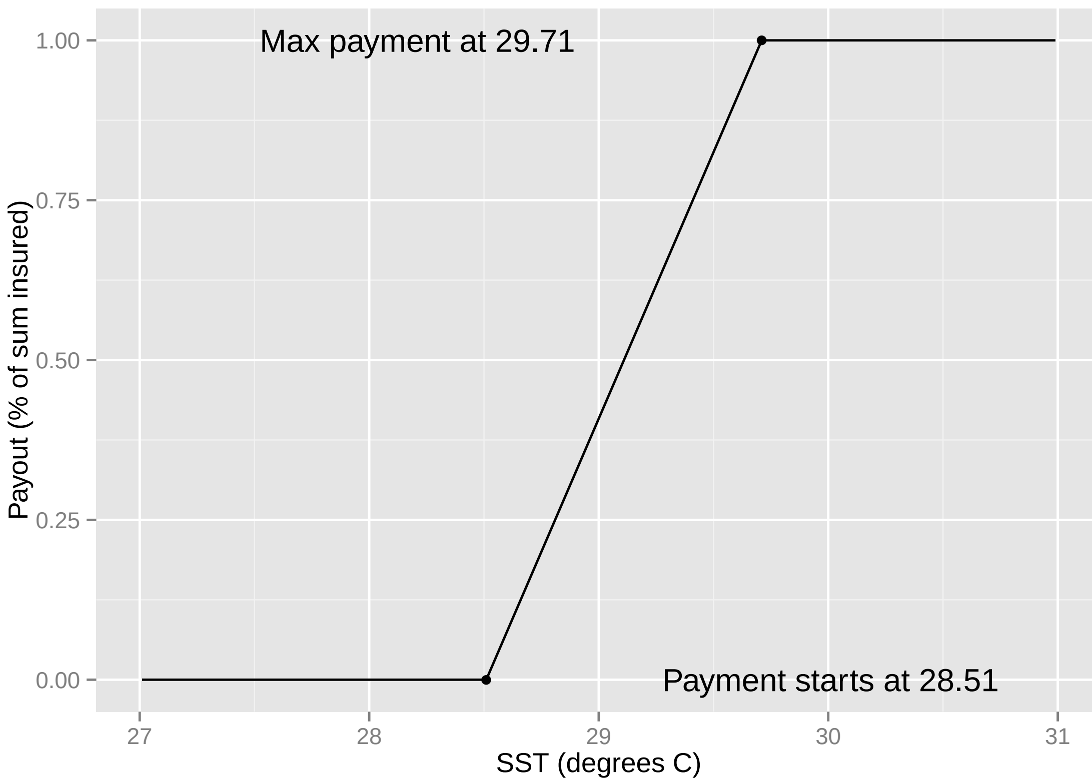


Figure 59: Payout function for call option on May SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations above the baseline

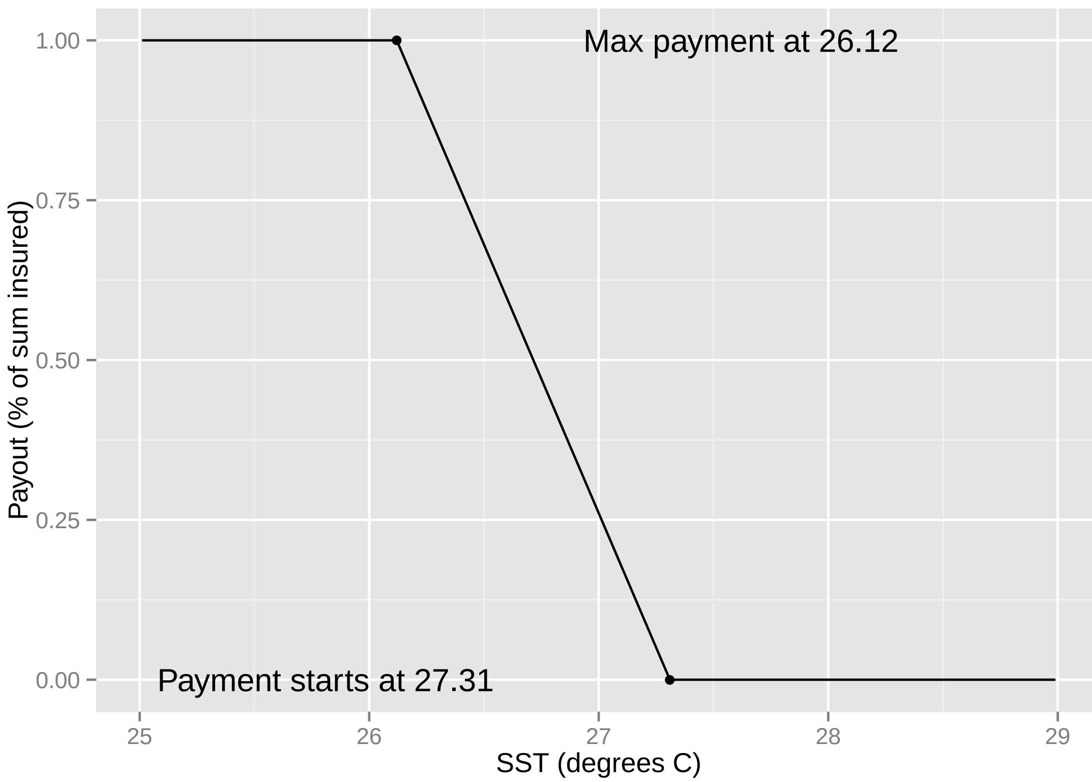


Figure 60: Payout function for put option on May SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

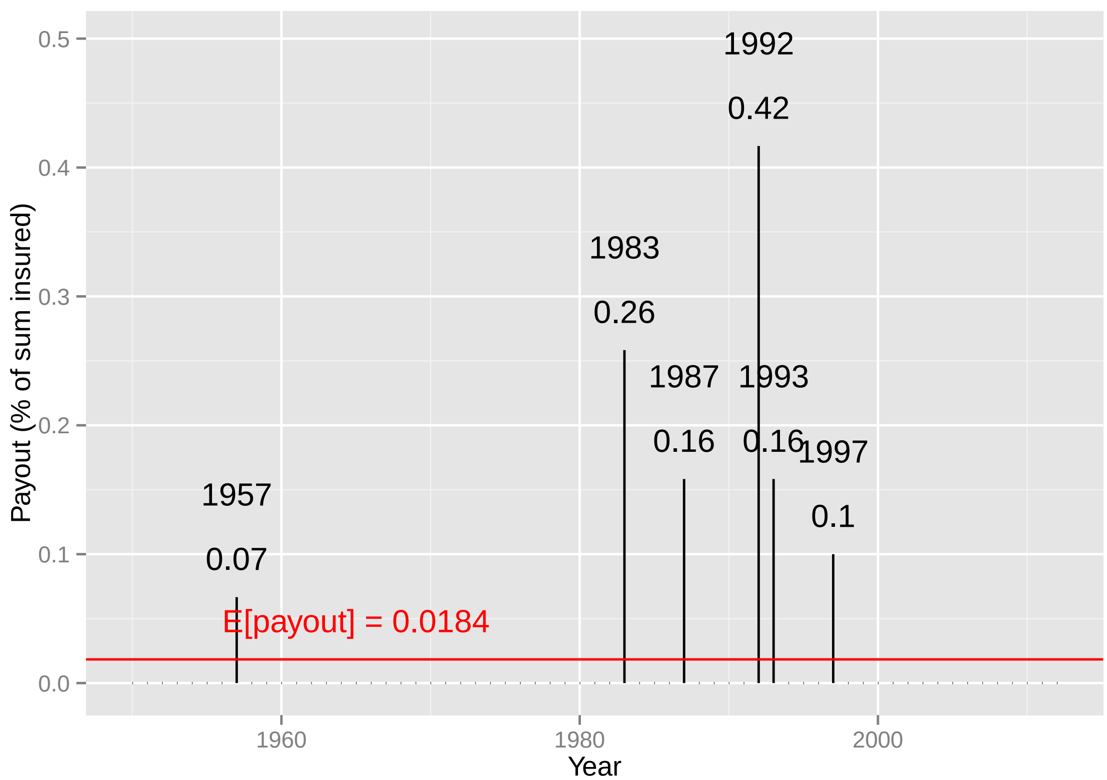


Figure 61: Historical burn on call option for May SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations above the baseline

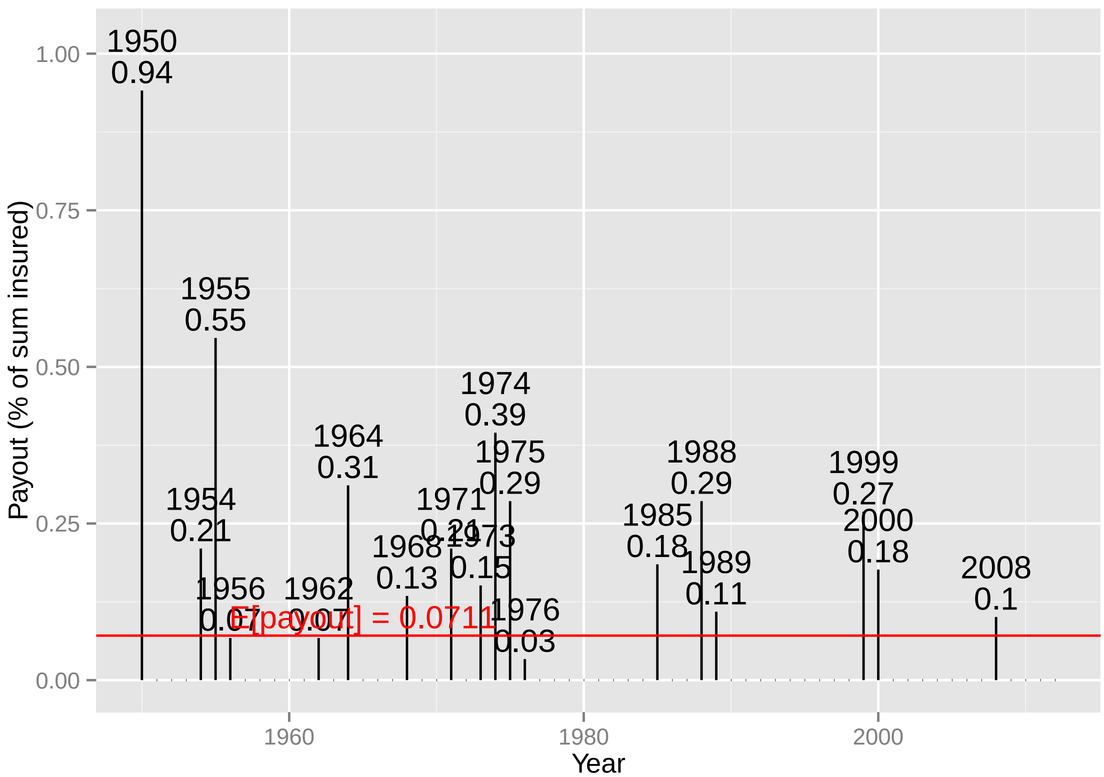


Figure 62: Historical burn on put option on May SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

Table 83: Bayesian regression linking May Niño 3.4 SST anomalies to average of relevant IRI ensemble forecasts

	mean	sd	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q	n_eff	Rhat
March forecast average covering May Niño 3.4 SST anomalies									
α	0.00	0.10	-0.20	-0.10	0.00	0.00	0.20	105894	1
β	0.60	0.30	0.00	0.40	0.60	0.70	1.10	95546	1
σ_y^2	0.10	0.10	0.00	0.10	0.10	0.20	0.30	57947	1
February forecast average covering May Niño 3.4 SST anomalies									
α	-0.10	0.10	-0.40	-0.20	-0.10	-0.10	0.10	100776	1
β	0.40	0.30	-0.10	0.30	0.40	0.60	0.90	89749	1
σ_y^2	0.10	0.10	0.00	0.10	0.10	0.20	0.40	56610	1
January forecast average covering May Niño 3.4 SST anomalies									
α	-0.10	0.10	-0.30	-0.20	-0.10	0.00	0.10	98543	1
β	0.30	0.20	-0.20	0.10	0.30	0.40	0.80	93801	1
σ_y^2	0.10	0.10	0.00	0.10	0.10	0.20	0.40	58133	1
December forecast average covering May Niño 3.4 SST anomalies									
α	-0.10	0.10	-0.40	-0.20	-0.10	-0.10	0.10	100456	1
β	0.20	0.20	-0.30	0.10	0.20	0.40	0.70	92197	1
σ_y^2	0.20	0.10	0.10	0.10	0.10	0.20	0.40	56313	1
November forecast average covering May Niño 3.4 SST anomalies									
α	-0.10	0.10	-0.40	-0.20	-0.10	-0.10	0.10	98588	1
β	0.20	0.30	-0.40	0.00	0.20	0.30	0.70	90016	1
σ_y^2	0.20	0.10	0.10	0.10	0.10	0.20	0.50	55965	1
October forecast average covering May Niño 3.4 SST anomalies									
α	-0.10	0.10	-0.40	-0.20	-0.10	-0.10	0.10	95062	1
β	0.20	0.30	-0.40	0.00	0.20	0.40	0.80	88214	1
σ_y^2	0.20	0.10	0.10	0.10	0.10	0.20	0.40	55894	1
September forecast average covering May Niño 3.4 SST anomalies									
α	-0.10	0.10	-0.40	-0.20	-0.10	-0.10	0.10	87146	1
β	0.20	0.40	-0.50	0.00	0.20	0.50	1.00	82225	1
σ_y^2	0.20	0.10	0.10	0.10	0.10	0.20	0.40	56226	1
August forecast average covering May Niño 3.4 SST anomalies									
α	-0.10	0.10	-0.40	-0.20	-0.10	-0.10	0.10	84688	1
β	0.20	0.40	-0.50	0.00	0.20	0.40	0.90	83599	1
σ_y^2	0.20	0.10	0.10	0.10	0.10	0.20	0.50	57159	1
July forecast average covering May Niño 3.4 SST anomalies									
α	-0.20	0.10	-0.40	-0.20	-0.20	-0.10	0.10	85575	1
β	0.00	0.40	-0.70	-0.20	0.00	0.30	0.80	81482	1
σ_y^2	0.20	0.10	0.00	0.10	0.10	0.20	0.40	54501	1

Table 84: Call option prices for May Nino 3.4 SST conditioned on IRI ensemble forecasts released in March

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	26.75	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	26.81	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	26.87	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	26.92	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	26.97	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	27.03	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	27.09	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	27.14	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	27.20	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	27.26	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	27.31	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	27.37	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	27.42	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	27.48	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	27.54	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	27.59	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	27.65	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	27.70	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	27.76	0.00	0.00	0.00	0.00	0.00
-0.10	0.01	27.82	0.00	0.00	0.00	0.00	0.05
0.00	0.01	27.87	0.00	0.00	0.00	0.00	0.07
0.10	0.01	27.93	0.00	0.00	0.00	0.00	0.13
0.20	0.01	27.99	0.00	0.00	0.00	0.00	0.19
0.30	0.02	28.04	0.00	0.00	0.00	0.00	0.25
0.40	0.02	28.10	0.00	0.00	0.00	0.00	0.30
0.50	0.03	28.15	0.00	0.00	0.00	0.00	0.36
0.60	0.04	28.21	0.00	0.00	0.00	0.00	0.42
0.70	0.06	28.27	0.00	0.00	0.00	0.01	0.49
0.80	0.07	28.32	0.00	0.00	0.00	0.07	0.56
0.90	0.10	28.38	0.00	0.00	0.00	0.12	0.63
1.00	0.12	28.44	0.00	0.00	0.00	0.18	0.71
1.10	0.14	28.49	0.00	0.00	0.00	0.23	0.78
1.20	0.17	28.55	0.00	0.00	0.03	0.29	0.86
1.30	0.20	28.60	0.00	0.00	0.08	0.34	0.93
1.40	0.23	28.66	0.00	0.00	0.12	0.40	1.00
1.50	0.27	28.72	0.00	0.00	0.17	0.46	1.00
1.60	0.30	28.77	0.00	0.00	0.22	0.51	1.00
1.70	0.34	28.83	0.00	0.00	0.26	0.57	1.00
1.80	0.37	28.88	0.00	0.00	0.31	0.63	1.00
1.90	0.40	28.94	0.00	0.03	0.35	0.69	1.00
2.00	0.44	28.99	0.00	0.06	0.40	0.74	1.00

Table 85: Call option prices for May Nino 3.4 SST conditioned on IRI ensemble forecasts released in February

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	26.95	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	27.00	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	27.04	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	27.08	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	27.12	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	27.16	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	27.20	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	27.24	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	27.29	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	27.33	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	27.37	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	27.41	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	27.45	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	27.49	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	27.53	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	27.57	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	27.61	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	27.66	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	27.70	0.00	0.00	0.00	0.00	0.00
-0.10	0.01	27.74	0.00	0.00	0.00	0.00	0.03
0.00	0.01	27.78	0.00	0.00	0.00	0.00	0.05
0.10	0.01	27.82	0.00	0.00	0.00	0.00	0.09
0.20	0.01	27.86	0.00	0.00	0.00	0.00	0.13
0.30	0.01	27.91	0.00	0.00	0.00	0.00	0.17
0.40	0.01	27.95	0.00	0.00	0.00	0.00	0.21
0.50	0.02	27.99	0.00	0.00	0.00	0.00	0.26
0.60	0.02	28.03	0.00	0.00	0.00	0.00	0.31
0.70	0.03	28.07	0.00	0.00	0.00	0.00	0.36
0.80	0.04	28.11	0.00	0.00	0.00	0.00	0.40
0.90	0.04	28.15	0.00	0.00	0.00	0.00	0.47
1.00	0.05	28.19	0.00	0.00	0.00	0.00	0.52
1.10	0.07	28.23	0.00	0.00	0.00	0.01	0.58
1.20	0.08	28.28	0.00	0.00	0.00	0.06	0.64
1.30	0.09	28.32	0.00	0.00	0.00	0.10	0.70
1.40	0.11	28.36	0.00	0.00	0.00	0.14	0.77
1.50	0.13	28.40	0.00	0.00	0.00	0.18	0.84
1.60	0.15	28.44	0.00	0.00	0.00	0.23	0.90
1.70	0.17	28.49	0.00	0.00	0.00	0.27	0.97
1.80	0.19	28.52	0.00	0.00	0.01	0.32	1.00
1.90	0.21	28.56	0.00	0.00	0.04	0.36	1.00
2.00	0.23	28.61	0.00	0.00	0.08	0.41	1.00

Table 86: Call option prices for May Nino 3.4 SST conditioned on IRI ensemble forecasts released in January

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.01	27.23	0.00	0.00	0.00	0.00	0.00
-1.90	0.01	27.25	0.00	0.00	0.00	0.00	0.00
-1.80	0.01	27.28	0.00	0.00	0.00	0.00	0.00
-1.70	0.01	27.31	0.00	0.00	0.00	0.00	0.00
-1.60	0.01	27.34	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	27.37	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	27.39	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	27.42	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	27.45	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	27.48	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	27.51	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	27.54	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	27.57	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	27.59	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	27.62	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	27.65	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	27.68	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	27.71	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	27.73	0.00	0.00	0.00	0.00	0.02
-0.10	0.01	27.76	0.00	0.00	0.00	0.00	0.04
0.00	0.01	27.79	0.00	0.00	0.00	0.00	0.06
0.10	0.01	27.82	0.00	0.00	0.00	0.00	0.09
0.20	0.01	27.85	0.00	0.00	0.00	0.00	0.12
0.30	0.01	27.87	0.00	0.00	0.00	0.00	0.14
0.40	0.01	27.90	0.00	0.00	0.00	0.00	0.17
0.50	0.01	27.94	0.00	0.00	0.00	0.00	0.20
0.60	0.02	27.96	0.00	0.00	0.00	0.00	0.24
0.70	0.02	27.99	0.00	0.00	0.00	0.00	0.28
0.80	0.02	28.02	0.00	0.00	0.00	0.00	0.31
0.90	0.03	28.05	0.00	0.00	0.00	0.00	0.36
1.00	0.03	28.08	0.00	0.00	0.00	0.00	0.39
1.10	0.04	28.10	0.00	0.00	0.00	0.00	0.43
1.20	0.05	28.13	0.00	0.00	0.00	0.00	0.50
1.30	0.06	28.16	0.00	0.00	0.00	0.00	0.53
1.40	0.06	28.19	0.00	0.00	0.00	0.00	0.58
1.50	0.07	28.22	0.00	0.00	0.00	0.02	0.63
1.60	0.09	28.25	0.00	0.00	0.00	0.06	0.68
1.70	0.10	28.28	0.00	0.00	0.00	0.09	0.73
1.80	0.11	28.30	0.00	0.00	0.00	0.12	0.78
1.90	0.12	28.33	0.00	0.00	0.00	0.15	0.84
2.00	0.13	28.36	0.00	0.00	0.00	0.18	0.88

Table 87: Call option prices for May Nino 3.4 SST conditioned on IRI ensemble forecasts released in December

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.01	27.37	0.00	0.00	0.00	0.00	0.15
-1.90	0.01	27.39	0.00	0.00	0.00	0.00	0.13
-1.80	0.01	27.41	0.00	0.00	0.00	0.00	0.13
-1.70	0.01	27.43	0.00	0.00	0.00	0.00	0.11
-1.60	0.01	27.46	0.00	0.00	0.00	0.00	0.11
-1.50	0.01	27.48	0.00	0.00	0.00	0.00	0.08
-1.40	0.01	27.50	0.00	0.00	0.00	0.00	0.07
-1.30	0.01	27.51	0.00	0.00	0.00	0.00	0.06
-1.20	0.01	27.54	0.00	0.00	0.00	0.00	0.07
-1.10	0.01	27.56	0.00	0.00	0.00	0.00	0.05
-1.00	0.01	27.58	0.00	0.00	0.00	0.00	0.06
-0.90	0.01	27.60	0.00	0.00	0.00	0.00	0.04
-0.80	0.01	27.62	0.00	0.00	0.00	0.00	0.04
-0.70	0.01	27.64	0.00	0.00	0.00	0.00	0.05
-0.60	0.01	27.66	0.00	0.00	0.00	0.00	0.04
-0.50	0.01	27.68	0.00	0.00	0.00	0.00	0.05
-0.40	0.01	27.70	0.00	0.00	0.00	0.00	0.05
-0.30	0.01	27.72	0.00	0.00	0.00	0.00	0.05
-0.20	0.01	27.74	0.00	0.00	0.00	0.00	0.07
-0.10	0.01	27.76	0.00	0.00	0.00	0.00	0.07
0.00	0.01	27.79	0.00	0.00	0.00	0.00	0.10
0.10	0.01	27.81	0.00	0.00	0.00	0.00	0.12
0.20	0.01	27.83	0.00	0.00	0.00	0.00	0.12
0.30	0.01	27.85	0.00	0.00	0.00	0.00	0.14
0.40	0.01	27.87	0.00	0.00	0.00	0.00	0.18
0.50	0.01	27.89	0.00	0.00	0.00	0.00	0.19
0.60	0.02	27.91	0.00	0.00	0.00	0.00	0.22
0.70	0.02	27.93	0.00	0.00	0.00	0.00	0.25
0.80	0.02	27.95	0.00	0.00	0.00	0.00	0.28
0.90	0.02	27.98	0.00	0.00	0.00	0.00	0.32
1.00	0.03	27.99	0.00	0.00	0.00	0.00	0.35
1.10	0.03	28.01	0.00	0.00	0.00	0.00	0.40
1.20	0.04	28.03	0.00	0.00	0.00	0.00	0.44
1.30	0.04	28.05	0.00	0.00	0.00	0.00	0.47
1.40	0.05	28.07	0.00	0.00	0.00	0.00	0.52
1.50	0.05	28.10	0.00	0.00	0.00	0.00	0.56
1.60	0.06	28.11	0.00	0.00	0.00	0.00	0.59
1.70	0.07	28.13	0.00	0.00	0.00	0.00	0.64
1.80	0.08	28.16	0.00	0.00	0.00	0.01	0.69
1.90	0.09	28.18	0.00	0.00	0.00	0.04	0.73
2.00	0.10	28.20	0.00	0.00	0.00	0.06	0.78

Table 88: Call option prices for May Nino 3.4 SST conditioned on IRI ensemble forecasts released in November

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.02	27.47	0.00	0.00	0.00	0.00	0.33
-1.90	0.02	27.48	0.00	0.00	0.00	0.00	0.30
-1.80	0.02	27.50	0.00	0.00	0.00	0.00	0.28
-1.70	0.02	27.52	0.00	0.00	0.00	0.00	0.28
-1.60	0.02	27.53	0.00	0.00	0.00	0.00	0.24
-1.50	0.01	27.54	0.00	0.00	0.00	0.00	0.23
-1.40	0.01	27.56	0.00	0.00	0.00	0.00	0.21
-1.30	0.01	27.57	0.00	0.00	0.00	0.00	0.19
-1.20	0.01	27.59	0.00	0.00	0.00	0.00	0.16
-1.10	0.01	27.61	0.00	0.00	0.00	0.00	0.15
-1.00	0.01	27.63	0.00	0.00	0.00	0.00	0.14
-0.90	0.01	27.64	0.00	0.00	0.00	0.00	0.12
-0.80	0.01	27.66	0.00	0.00	0.00	0.00	0.12
-0.70	0.01	27.67	0.00	0.00	0.00	0.00	0.11
-0.60	0.01	27.69	0.00	0.00	0.00	0.00	0.10
-0.50	0.01	27.70	0.00	0.00	0.00	0.00	0.09
-0.40	0.01	27.72	0.00	0.00	0.00	0.00	0.08
-0.30	0.01	27.73	0.00	0.00	0.00	0.00	0.09
-0.20	0.01	27.75	0.00	0.00	0.00	0.00	0.09
-0.10	0.01	27.77	0.00	0.00	0.00	0.00	0.10
0.00	0.01	27.78	0.00	0.00	0.00	0.00	0.12
0.10	0.01	27.80	0.00	0.00	0.00	0.00	0.12
0.20	0.01	27.81	0.00	0.00	0.00	0.00	0.13
0.30	0.01	27.83	0.00	0.00	0.00	0.00	0.15
0.40	0.01	27.85	0.00	0.00	0.00	0.00	0.17
0.50	0.01	27.86	0.00	0.00	0.00	0.00	0.19
0.60	0.02	27.88	0.00	0.00	0.00	0.00	0.22
0.70	0.02	27.89	0.00	0.00	0.00	0.00	0.24
0.80	0.02	27.91	0.00	0.00	0.00	0.00	0.27
0.90	0.02	27.92	0.00	0.00	0.00	0.00	0.31
1.00	0.03	27.94	0.00	0.00	0.00	0.00	0.35
1.10	0.03	27.95	0.00	0.00	0.00	0.00	0.37
1.20	0.03	27.97	0.00	0.00	0.00	0.00	0.42
1.30	0.04	27.99	0.00	0.00	0.00	0.00	0.46
1.40	0.04	28.00	0.00	0.00	0.00	0.00	0.50
1.50	0.05	28.02	0.00	0.00	0.00	0.00	0.53
1.60	0.05	28.03	0.00	0.00	0.00	0.00	0.59
1.70	0.06	28.05	0.00	0.00	0.00	0.00	0.62
1.80	0.07	28.06	0.00	0.00	0.00	0.00	0.67
1.90	0.08	28.08	0.00	0.00	0.00	0.00	0.74
2.00	0.08	28.09	0.00	0.00	0.00	0.00	0.76

Table 89: Call option prices for May Nino 3.4 SST conditioned on IRI ensemble forecasts released in October

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.02	27.38	0.00	0.00	0.00	0.00	0.31
-1.90	0.02	27.40	0.00	0.00	0.00	0.00	0.28
-1.80	0.02	27.42	0.00	0.00	0.00	0.00	0.25
-1.70	0.02	27.44	0.00	0.00	0.00	0.00	0.23
-1.60	0.01	27.45	0.00	0.00	0.00	0.00	0.21
-1.50	0.01	27.47	0.00	0.00	0.00	0.00	0.19
-1.40	0.01	27.49	0.00	0.00	0.00	0.00	0.17
-1.30	0.01	27.52	0.00	0.00	0.00	0.00	0.16
-1.20	0.01	27.53	0.00	0.00	0.00	0.00	0.14
-1.10	0.01	27.55	0.00	0.00	0.00	0.00	0.13
-1.00	0.01	27.58	0.00	0.00	0.00	0.00	0.11
-0.90	0.01	27.59	0.00	0.00	0.00	0.00	0.11
-0.80	0.01	27.62	0.00	0.00	0.00	0.00	0.10
-0.70	0.01	27.64	0.00	0.00	0.00	0.00	0.08
-0.60	0.01	27.66	0.00	0.00	0.00	0.00	0.09
-0.50	0.01	27.68	0.00	0.00	0.00	0.00	0.07
-0.40	0.01	27.70	0.00	0.00	0.00	0.00	0.07
-0.30	0.01	27.72	0.00	0.00	0.00	0.00	0.07
-0.20	0.01	27.73	0.00	0.00	0.00	0.00	0.08
-0.10	0.01	27.76	0.00	0.00	0.00	0.00	0.08
0.00	0.01	27.77	0.00	0.00	0.00	0.00	0.10
0.10	0.01	27.80	0.00	0.00	0.00	0.00	0.11
0.20	0.01	27.81	0.00	0.00	0.00	0.00	0.14
0.30	0.01	27.83	0.00	0.00	0.00	0.00	0.15
0.40	0.01	27.85	0.00	0.00	0.00	0.00	0.17
0.50	0.01	27.88	0.00	0.00	0.00	0.00	0.20
0.60	0.02	27.90	0.00	0.00	0.00	0.00	0.24
0.70	0.02	27.92	0.00	0.00	0.00	0.00	0.28
0.80	0.02	27.94	0.00	0.00	0.00	0.00	0.31
0.90	0.02	27.96	0.00	0.00	0.00	0.00	0.33
1.00	0.03	27.98	0.00	0.00	0.00	0.00	0.39
1.10	0.03	28.00	0.00	0.00	0.00	0.00	0.42
1.20	0.04	28.02	0.00	0.00	0.00	0.00	0.47
1.30	0.05	28.03	0.00	0.00	0.00	0.00	0.52
1.40	0.05	28.05	0.00	0.00	0.00	0.00	0.57
1.50	0.06	28.07	0.00	0.00	0.00	0.00	0.61
1.60	0.07	28.10	0.00	0.00	0.00	0.00	0.67
1.70	0.08	28.11	0.00	0.00	0.00	0.00	0.72
1.80	0.09	28.14	0.00	0.00	0.00	0.02	0.79
1.90	0.10	28.15	0.00	0.00	0.00	0.05	0.83
2.00	0.11	28.17	0.00	0.00	0.00	0.08	0.89

Table 90: Call option prices for May Nino 3.4 SST conditioned on IRI ensemble forecasts released in September

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.03	27.28	0.00	0.00	0.00	0.00	0.47
-1.90	0.03	27.30	0.00	0.00	0.00	0.00	0.42
-1.80	0.02	27.33	0.00	0.00	0.00	0.00	0.40
-1.70	0.02	27.35	0.00	0.00	0.00	0.00	0.37
-1.60	0.02	27.37	0.00	0.00	0.00	0.00	0.33
-1.50	0.02	27.40	0.00	0.00	0.00	0.00	0.31
-1.40	0.02	27.42	0.00	0.00	0.00	0.00	0.28
-1.30	0.02	27.45	0.00	0.00	0.00	0.00	0.25
-1.20	0.01	27.47	0.00	0.00	0.00	0.00	0.22
-1.10	0.01	27.49	0.00	0.00	0.00	0.00	0.19
-1.00	0.01	27.52	0.00	0.00	0.00	0.00	0.18
-0.90	0.01	27.54	0.00	0.00	0.00	0.00	0.14
-0.80	0.01	27.57	0.00	0.00	0.00	0.00	0.13
-0.70	0.01	27.59	0.00	0.00	0.00	0.00	0.11
-0.60	0.01	27.61	0.00	0.00	0.00	0.00	0.10
-0.50	0.01	27.64	0.00	0.00	0.00	0.00	0.08
-0.40	0.01	27.67	0.00	0.00	0.00	0.00	0.08
-0.30	0.01	27.69	0.00	0.00	0.00	0.00	0.08
-0.20	0.01	27.71	0.00	0.00	0.00	0.00	0.07
-0.10	0.01	27.74	0.00	0.00	0.00	0.00	0.08
0.00	0.01	27.76	0.00	0.00	0.00	0.00	0.08
0.10	0.01	27.79	0.00	0.00	0.00	0.00	0.10
0.20	0.01	27.81	0.00	0.00	0.00	0.00	0.12
0.30	0.01	27.83	0.00	0.00	0.00	0.00	0.14
0.40	0.01	27.86	0.00	0.00	0.00	0.00	0.17
0.50	0.01	27.88	0.00	0.00	0.00	0.00	0.22
0.60	0.02	27.90	0.00	0.00	0.00	0.00	0.25
0.70	0.02	27.93	0.00	0.00	0.00	0.00	0.29
0.80	0.03	27.95	0.00	0.00	0.00	0.00	0.33
0.90	0.03	27.98	0.00	0.00	0.00	0.00	0.41
1.00	0.04	28.01	0.00	0.00	0.00	0.00	0.45
1.10	0.04	28.03	0.00	0.00	0.00	0.00	0.50
1.20	0.05	28.05	0.00	0.00	0.00	0.00	0.56
1.30	0.06	28.07	0.00	0.00	0.00	0.00	0.62
1.40	0.07	28.10	0.00	0.00	0.00	0.00	0.69
1.50	0.08	28.12	0.00	0.00	0.00	0.01	0.75
1.60	0.10	28.15	0.00	0.00	0.00	0.04	0.83
1.70	0.11	28.17	0.00	0.00	0.00	0.08	0.90
1.80	0.12	28.20	0.00	0.00	0.00	0.12	0.95
1.90	0.13	28.22	0.00	0.00	0.00	0.15	1.00
2.00	0.15	28.24	0.00	0.00	0.00	0.19	1.00

Table 91: Call option prices for May Nino 3.4 SST conditioned on IRI ensemble forecasts released in August

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.04	27.41	0.00	0.00	0.00	0.00	0.59
-1.90	0.03	27.42	0.00	0.00	0.00	0.00	0.53
-1.80	0.03	27.44	0.00	0.00	0.00	0.00	0.53
-1.70	0.03	27.46	0.00	0.00	0.00	0.00	0.48
-1.60	0.03	27.48	0.00	0.00	0.00	0.00	0.44
-1.50	0.03	27.50	0.00	0.00	0.00	0.00	0.39
-1.40	0.02	27.52	0.00	0.00	0.00	0.00	0.36
-1.30	0.02	27.53	0.00	0.00	0.00	0.00	0.32
-1.20	0.02	27.55	0.00	0.00	0.00	0.00	0.30
-1.10	0.02	27.57	0.00	0.00	0.00	0.00	0.27
-1.00	0.02	27.59	0.00	0.00	0.00	0.00	0.23
-0.90	0.01	27.61	0.00	0.00	0.00	0.00	0.21
-0.80	0.01	27.62	0.00	0.00	0.00	0.00	0.19
-0.70	0.01	27.64	0.00	0.00	0.00	0.00	0.16
-0.60	0.01	27.66	0.00	0.00	0.00	0.00	0.15
-0.50	0.01	27.68	0.00	0.00	0.00	0.00	0.13
-0.40	0.01	27.70	0.00	0.00	0.00	0.00	0.12
-0.30	0.01	27.72	0.00	0.00	0.00	0.00	0.11
-0.20	0.01	27.73	0.00	0.00	0.00	0.00	0.11
-0.10	0.01	27.75	0.00	0.00	0.00	0.00	0.10
0.00	0.01	27.77	0.00	0.00	0.00	0.00	0.11
0.10	0.01	27.79	0.00	0.00	0.00	0.00	0.12
0.20	0.01	27.80	0.00	0.00	0.00	0.00	0.12
0.30	0.01	27.82	0.00	0.00	0.00	0.00	0.14
0.40	0.01	27.84	0.00	0.00	0.00	0.00	0.18
0.50	0.01	27.86	0.00	0.00	0.00	0.00	0.20
0.60	0.02	27.88	0.00	0.00	0.00	0.00	0.23
0.70	0.02	27.90	0.00	0.00	0.00	0.00	0.27
0.80	0.02	27.92	0.00	0.00	0.00	0.00	0.31
0.90	0.03	27.94	0.00	0.00	0.00	0.00	0.37
1.00	0.03	27.95	0.00	0.00	0.00	0.00	0.42
1.10	0.04	27.97	0.00	0.00	0.00	0.00	0.46
1.20	0.05	27.99	0.00	0.00	0.00	0.00	0.53
1.30	0.05	28.01	0.00	0.00	0.00	0.00	0.57
1.40	0.06	28.03	0.00	0.00	0.00	0.00	0.63
1.50	0.07	28.04	0.00	0.00	0.00	0.00	0.68
1.60	0.08	28.06	0.00	0.00	0.00	0.00	0.76
1.70	0.09	28.08	0.00	0.00	0.00	0.00	0.81
1.80	0.10	28.10	0.00	0.00	0.00	0.04	0.87
1.90	0.11	28.12	0.00	0.00	0.00	0.06	0.94
2.00	0.12	28.13	0.00	0.00	0.00	0.10	0.99

Table 92: Call option prices for May Nino 3.4 SST conditioned on IRI ensemble forecasts released in July

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.07	27.67	0.00	0.00	0.00	0.00	0.84
-1.90	0.06	27.68	0.00	0.00	0.00	0.00	0.78
-1.80	0.06	27.68	0.00	0.00	0.00	0.00	0.73
-1.70	0.05	27.68	0.00	0.00	0.00	0.00	0.67
-1.60	0.05	27.69	0.00	0.00	0.00	0.00	0.63
-1.50	0.04	27.69	0.00	0.00	0.00	0.00	0.57
-1.40	0.04	27.69	0.00	0.00	0.00	0.00	0.51
-1.30	0.03	27.70	0.00	0.00	0.00	0.00	0.48
-1.20	0.03	27.70	0.00	0.00	0.00	0.00	0.42
-1.10	0.03	27.71	0.00	0.00	0.00	0.00	0.39
-1.00	0.02	27.71	0.00	0.00	0.00	0.00	0.34
-0.90	0.02	27.71	0.00	0.00	0.00	0.00	0.30
-0.80	0.02	27.72	0.00	0.00	0.00	0.00	0.26
-0.70	0.01	27.72	0.00	0.00	0.00	0.00	0.22
-0.60	0.01	27.72	0.00	0.00	0.00	0.00	0.18
-0.50	0.01	27.73	0.00	0.00	0.00	0.00	0.16
-0.40	0.01	27.73	0.00	0.00	0.00	0.00	0.12
-0.30	0.01	27.73	0.00	0.00	0.00	0.00	0.11
-0.20	0.01	27.74	0.00	0.00	0.00	0.00	0.08
-0.10	0.01	27.74	0.00	0.00	0.00	0.00	0.07
0.00	0.01	27.75	0.00	0.00	0.00	0.00	0.06
0.10	0.01	27.75	0.00	0.00	0.00	0.00	0.06
0.20	0.01	27.75	0.00	0.00	0.00	0.00	0.06
0.30	0.01	27.76	0.00	0.00	0.00	0.00	0.07
0.40	0.01	27.76	0.00	0.00	0.00	0.00	0.08
0.50	0.01	27.76	0.00	0.00	0.00	0.00	0.10
0.60	0.01	27.77	0.00	0.00	0.00	0.00	0.13
0.70	0.01	27.77	0.00	0.00	0.00	0.00	0.16
0.80	0.01	27.78	0.00	0.00	0.00	0.00	0.20
0.90	0.02	27.78	0.00	0.00	0.00	0.00	0.23
1.00	0.02	27.79	0.00	0.00	0.00	0.00	0.29
1.10	0.02	27.79	0.00	0.00	0.00	0.00	0.33
1.20	0.03	27.79	0.00	0.00	0.00	0.00	0.37
1.30	0.03	27.79	0.00	0.00	0.00	0.00	0.41
1.40	0.03	27.79	0.00	0.00	0.00	0.00	0.46
1.50	0.04	27.80	0.00	0.00	0.00	0.00	0.51
1.60	0.04	27.80	0.00	0.00	0.00	0.00	0.57
1.70	0.05	27.81	0.00	0.00	0.00	0.00	0.61
1.80	0.06	27.81	0.00	0.00	0.00	0.00	0.68
1.90	0.06	27.82	0.00	0.00	0.00	0.00	0.73
2.00	0.07	27.82	0.00	0.00	0.00	0.00	0.80

Table 93: Put option prices for May Nino 3.4 SST conditioned on IRI ensemble forecasts released in March

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.48	26.75	0.00	0.14	0.47	0.81	1.00
-1.90	0.45	26.81	0.00	0.10	0.42	0.75	1.00
-1.80	0.41	26.87	0.00	0.06	0.37	0.69	1.00
-1.70	0.38	26.92	0.00	0.02	0.33	0.63	1.00
-1.60	0.34	26.97	0.00	0.00	0.28	0.57	1.00
-1.50	0.31	27.03	0.00	0.00	0.23	0.52	1.00
-1.40	0.27	27.09	0.00	0.00	0.18	0.46	1.00
-1.30	0.24	27.14	0.00	0.00	0.14	0.40	0.98
-1.20	0.20	27.20	0.00	0.00	0.09	0.34	0.90
-1.10	0.17	27.26	0.00	0.00	0.04	0.29	0.83
-1.00	0.14	27.31	0.00	0.00	0.00	0.24	0.75
-0.90	0.12	27.37	0.00	0.00	0.00	0.18	0.68
-0.80	0.09	27.42	0.00	0.00	0.00	0.13	0.62
-0.70	0.07	27.48	0.00	0.00	0.00	0.07	0.55
-0.60	0.06	27.54	0.00	0.00	0.00	0.02	0.49
-0.50	0.04	27.59	0.00	0.00	0.00	0.00	0.42
-0.40	0.03	27.65	0.00	0.00	0.00	0.00	0.36
-0.30	0.02	27.70	0.00	0.00	0.00	0.00	0.30
-0.20	0.02	27.76	0.00	0.00	0.00	0.00	0.24
-0.10	0.01	27.82	0.00	0.00	0.00	0.00	0.19
0.00	0.01	27.87	0.00	0.00	0.00	0.00	0.15
0.10	0.01	27.93	0.00	0.00	0.00	0.00	0.11
0.20	0.01	27.99	0.00	0.00	0.00	0.00	0.07
0.30	0.00	28.04	0.00	0.00	0.00	0.00	0.02
0.40	0.00	28.10	0.00	0.00	0.00	0.00	0.00
0.50	0.00	28.15	0.00	0.00	0.00	0.00	0.00
0.60	0.00	28.21	0.00	0.00	0.00	0.00	0.00
0.70	0.00	28.27	0.00	0.00	0.00	0.00	0.00
0.80	0.00	28.32	0.00	0.00	0.00	0.00	0.00
0.90	0.00	28.38	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.44	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.49	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.55	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.60	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.66	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.72	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.77	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.83	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.88	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.94	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.99	0.00	0.00	0.00	0.00	0.00

Table 94: Put option prices for May Nino 3.4 SST conditioned on IRI ensemble forecasts released in February

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.37	26.95	0.00	0.00	0.30	0.63	1.00
-1.90	0.34	27.00	0.00	0.00	0.26	0.59	1.00
-1.80	0.32	27.04	0.00	0.00	0.23	0.54	1.00
-1.70	0.29	27.08	0.00	0.00	0.20	0.50	1.00
-1.60	0.27	27.12	0.00	0.00	0.16	0.45	1.00
-1.50	0.24	27.16	0.00	0.00	0.13	0.41	1.00
-1.40	0.22	27.20	0.00	0.00	0.09	0.36	1.00
-1.30	0.19	27.24	0.00	0.00	0.06	0.32	0.93
-1.20	0.17	27.29	0.00	0.00	0.02	0.28	0.87
-1.10	0.15	27.33	0.00	0.00	0.00	0.23	0.80
-1.00	0.13	27.37	0.00	0.00	0.00	0.20	0.74
-0.90	0.11	27.41	0.00	0.00	0.00	0.15	0.68
-0.80	0.09	27.45	0.00	0.00	0.00	0.11	0.64
-0.70	0.08	27.49	0.00	0.00	0.00	0.07	0.59
-0.60	0.06	27.53	0.00	0.00	0.00	0.03	0.54
-0.50	0.05	27.57	0.00	0.00	0.00	0.00	0.48
-0.40	0.04	27.61	0.00	0.00	0.00	0.00	0.42
-0.30	0.03	27.66	0.00	0.00	0.00	0.00	0.38
-0.20	0.03	27.70	0.00	0.00	0.00	0.00	0.35
-0.10	0.02	27.74	0.00	0.00	0.00	0.00	0.30
0.00	0.02	27.78	0.00	0.00	0.00	0.00	0.26
0.10	0.02	27.82	0.00	0.00	0.00	0.00	0.23
0.20	0.01	27.86	0.00	0.00	0.00	0.00	0.20
0.30	0.01	27.91	0.00	0.00	0.00	0.00	0.17
0.40	0.01	27.95	0.00	0.00	0.00	0.00	0.14
0.50	0.01	27.99	0.00	0.00	0.00	0.00	0.13
0.60	0.01	28.03	0.00	0.00	0.00	0.00	0.10
0.70	0.01	28.07	0.00	0.00	0.00	0.00	0.09
0.80	0.01	28.11	0.00	0.00	0.00	0.00	0.07
0.90	0.01	28.15	0.00	0.00	0.00	0.00	0.05
1.00	0.01	28.19	0.00	0.00	0.00	0.00	0.04
1.10	0.01	28.23	0.00	0.00	0.00	0.00	0.04
1.20	0.01	28.28	0.00	0.00	0.00	0.00	0.02
1.30	0.01	28.32	0.00	0.00	0.00	0.00	0.03
1.40	0.01	28.36	0.00	0.00	0.00	0.00	0.00
1.50	0.01	28.40	0.00	0.00	0.00	0.00	0.01
1.60	0.01	28.44	0.00	0.00	0.00	0.00	0.01
1.70	0.01	28.49	0.00	0.00	0.00	0.00	0.00
1.80	0.01	28.52	0.00	0.00	0.00	0.00	0.01
1.90	0.01	28.56	0.00	0.00	0.00	0.00	0.00
2.00	0.01	28.61	0.00	0.00	0.00	0.00	0.02

Table 95: Put option prices for May Nino 3.4 SST conditioned on IRI ensemble forecasts released in January

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.23	27.23	0.00	0.00	0.07	0.39	1.00
-1.90	0.21	27.25	0.00	0.00	0.05	0.36	1.00
-1.80	0.19	27.28	0.00	0.00	0.03	0.32	0.99
-1.70	0.18	27.31	0.00	0.00	0.00	0.30	0.94
-1.60	0.16	27.34	0.00	0.00	0.00	0.26	0.89
-1.50	0.15	27.37	0.00	0.00	0.00	0.23	0.84
-1.40	0.13	27.39	0.00	0.00	0.00	0.20	0.79
-1.30	0.12	27.42	0.00	0.00	0.00	0.17	0.74
-1.20	0.10	27.45	0.00	0.00	0.00	0.13	0.70
-1.10	0.09	27.48	0.00	0.00	0.00	0.10	0.66
-1.00	0.08	27.51	0.00	0.00	0.00	0.07	0.60
-0.90	0.07	27.54	0.00	0.00	0.00	0.04	0.57
-0.80	0.06	27.57	0.00	0.00	0.00	0.01	0.52
-0.70	0.05	27.59	0.00	0.00	0.00	0.00	0.47
-0.60	0.04	27.62	0.00	0.00	0.00	0.00	0.44
-0.50	0.04	27.65	0.00	0.00	0.00	0.00	0.41
-0.40	0.03	27.68	0.00	0.00	0.00	0.00	0.37
-0.30	0.03	27.71	0.00	0.00	0.00	0.00	0.34
-0.20	0.02	27.73	0.00	0.00	0.00	0.00	0.30
-0.10	0.02	27.76	0.00	0.00	0.00	0.00	0.28
0.00	0.02	27.79	0.00	0.00	0.00	0.00	0.26
0.10	0.02	27.82	0.00	0.00	0.00	0.00	0.22
0.20	0.01	27.85	0.00	0.00	0.00	0.00	0.22
0.30	0.01	27.87	0.00	0.00	0.00	0.00	0.19
0.40	0.01	27.90	0.00	0.00	0.00	0.00	0.18
0.50	0.01	27.94	0.00	0.00	0.00	0.00	0.16
0.60	0.01	27.96	0.00	0.00	0.00	0.00	0.15
0.70	0.01	27.99	0.00	0.00	0.00	0.00	0.13
0.80	0.01	28.02	0.00	0.00	0.00	0.00	0.14
0.90	0.01	28.05	0.00	0.00	0.00	0.00	0.13
1.00	0.01	28.08	0.00	0.00	0.00	0.00	0.12
1.10	0.01	28.10	0.00	0.00	0.00	0.00	0.11
1.20	0.01	28.13	0.00	0.00	0.00	0.00	0.12
1.30	0.01	28.16	0.00	0.00	0.00	0.00	0.12
1.40	0.01	28.19	0.00	0.00	0.00	0.00	0.11
1.50	0.01	28.22	0.00	0.00	0.00	0.00	0.12
1.60	0.01	28.25	0.00	0.00	0.00	0.00	0.12
1.70	0.01	28.28	0.00	0.00	0.00	0.00	0.12
1.80	0.01	28.30	0.00	0.00	0.00	0.00	0.13
1.90	0.01	28.33	0.00	0.00	0.00	0.00	0.14
2.00	0.01	28.36	0.00	0.00	0.00	0.00	0.14

Table 96: Put option prices for May Nino 3.4 SST conditioned on IRI ensemble forecasts released in December

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.18	27.37	0.00	0.00	0.00	0.29	1.00
-1.90	0.16	27.39	0.00	0.00	0.00	0.26	0.99
-1.80	0.15	27.41	0.00	0.00	0.00	0.23	0.94
-1.70	0.14	27.43	0.00	0.00	0.00	0.21	0.90
-1.60	0.13	27.46	0.00	0.00	0.00	0.18	0.84
-1.50	0.12	27.48	0.00	0.00	0.00	0.16	0.80
-1.40	0.11	27.50	0.00	0.00	0.00	0.13	0.76
-1.30	0.10	27.51	0.00	0.00	0.00	0.10	0.72
-1.20	0.09	27.54	0.00	0.00	0.00	0.08	0.68
-1.10	0.08	27.56	0.00	0.00	0.00	0.05	0.63
-1.00	0.07	27.58	0.00	0.00	0.00	0.03	0.59
-0.90	0.06	27.60	0.00	0.00	0.00	0.01	0.56
-0.80	0.06	27.62	0.00	0.00	0.00	0.00	0.52
-0.70	0.05	27.64	0.00	0.00	0.00	0.00	0.47
-0.60	0.04	27.66	0.00	0.00	0.00	0.00	0.46
-0.50	0.04	27.68	0.00	0.00	0.00	0.00	0.42
-0.40	0.03	27.70	0.00	0.00	0.00	0.00	0.39
-0.30	0.03	27.72	0.00	0.00	0.00	0.00	0.36
-0.20	0.03	27.74	0.00	0.00	0.00	0.00	0.34
-0.10	0.02	27.76	0.00	0.00	0.00	0.00	0.32
0.00	0.02	27.79	0.00	0.00	0.00	0.00	0.30
0.10	0.02	27.81	0.00	0.00	0.00	0.00	0.28
0.20	0.02	27.83	0.00	0.00	0.00	0.00	0.27
0.30	0.02	27.85	0.00	0.00	0.00	0.00	0.26
0.40	0.02	27.87	0.00	0.00	0.00	0.00	0.24
0.50	0.02	27.89	0.00	0.00	0.00	0.00	0.24
0.60	0.02	27.91	0.00	0.00	0.00	0.00	0.24
0.70	0.02	27.93	0.00	0.00	0.00	0.00	0.23
0.80	0.01	27.95	0.00	0.00	0.00	0.00	0.21
0.90	0.01	27.98	0.00	0.00	0.00	0.00	0.22
1.00	0.01	27.99	0.00	0.00	0.00	0.00	0.22
1.10	0.02	28.01	0.00	0.00	0.00	0.00	0.23
1.20	0.02	28.03	0.00	0.00	0.00	0.00	0.22
1.30	0.02	28.05	0.00	0.00	0.00	0.00	0.24
1.40	0.02	28.07	0.00	0.00	0.00	0.00	0.25
1.50	0.02	28.10	0.00	0.00	0.00	0.00	0.25
1.60	0.02	28.11	0.00	0.00	0.00	0.00	0.27
1.70	0.02	28.13	0.00	0.00	0.00	0.00	0.27
1.80	0.02	28.16	0.00	0.00	0.00	0.00	0.28
1.90	0.02	28.18	0.00	0.00	0.00	0.00	0.29
2.00	0.02	28.20	0.00	0.00	0.00	0.00	0.31

Table 97: Put option prices for May Nino 3.4 SST conditioned on IRI ensemble forecasts released in November

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.16	27.47	0.00	0.00	0.00	0.24	1.00
-1.90	0.15	27.48	0.00	0.00	0.00	0.22	1.00
-1.80	0.14	27.50	0.00	0.00	0.00	0.20	0.96
-1.70	0.13	27.52	0.00	0.00	0.00	0.17	0.92
-1.60	0.12	27.53	0.00	0.00	0.00	0.14	0.87
-1.50	0.11	27.54	0.00	0.00	0.00	0.12	0.84
-1.40	0.10	27.56	0.00	0.00	0.00	0.10	0.78
-1.30	0.09	27.57	0.00	0.00	0.00	0.08	0.74
-1.20	0.09	27.59	0.00	0.00	0.00	0.05	0.70
-1.10	0.08	27.61	0.00	0.00	0.00	0.03	0.65
-1.00	0.07	27.63	0.00	0.00	0.00	0.01	0.61
-0.90	0.06	27.64	0.00	0.00	0.00	0.00	0.57
-0.80	0.06	27.66	0.00	0.00	0.00	0.00	0.53
-0.70	0.05	27.67	0.00	0.00	0.00	0.00	0.49
-0.60	0.04	27.69	0.00	0.00	0.00	0.00	0.46
-0.50	0.04	27.70	0.00	0.00	0.00	0.00	0.44
-0.40	0.04	27.72	0.00	0.00	0.00	0.00	0.41
-0.30	0.03	27.73	0.00	0.00	0.00	0.00	0.38
-0.20	0.03	27.75	0.00	0.00	0.00	0.00	0.36
-0.10	0.03	27.77	0.00	0.00	0.00	0.00	0.34
0.00	0.02	27.78	0.00	0.00	0.00	0.00	0.31
0.10	0.02	27.80	0.00	0.00	0.00	0.00	0.30
0.20	0.02	27.81	0.00	0.00	0.00	0.00	0.29
0.30	0.02	27.83	0.00	0.00	0.00	0.00	0.29
0.40	0.02	27.85	0.00	0.00	0.00	0.00	0.26
0.50	0.02	27.86	0.00	0.00	0.00	0.00	0.29
0.60	0.02	27.88	0.00	0.00	0.00	0.00	0.28
0.70	0.02	27.89	0.00	0.00	0.00	0.00	0.29
0.80	0.02	27.91	0.00	0.00	0.00	0.00	0.28
0.90	0.02	27.92	0.00	0.00	0.00	0.00	0.28
1.00	0.02	27.94	0.00	0.00	0.00	0.00	0.29
1.10	0.02	27.95	0.00	0.00	0.00	0.00	0.30
1.20	0.02	27.97	0.00	0.00	0.00	0.00	0.34
1.30	0.02	27.99	0.00	0.00	0.00	0.00	0.34
1.40	0.02	28.00	0.00	0.00	0.00	0.00	0.35
1.50	0.03	28.02	0.00	0.00	0.00	0.00	0.36
1.60	0.03	28.03	0.00	0.00	0.00	0.00	0.37
1.70	0.03	28.05	0.00	0.00	0.00	0.00	0.41
1.80	0.03	28.06	0.00	0.00	0.00	0.00	0.43
1.90	0.03	28.08	0.00	0.00	0.00	0.00	0.44
2.00	0.03	28.09	0.00	0.00	0.00	0.00	0.48

Table 98: Put option prices for May Nino 3.4 SST conditioned on IRI ensemble forecasts released in October

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.20	27.38	0.00	0.00	0.00	0.33	1.00
-1.90	0.19	27.40	0.00	0.00	0.00	0.30	1.00
-1.80	0.17	27.42	0.00	0.00	0.00	0.27	1.00
-1.70	0.16	27.44	0.00	0.00	0.00	0.25	1.00
-1.60	0.15	27.45	0.00	0.00	0.00	0.22	0.98
-1.50	0.14	27.47	0.00	0.00	0.00	0.19	0.93
-1.40	0.13	27.49	0.00	0.00	0.00	0.16	0.86
-1.30	0.11	27.52	0.00	0.00	0.00	0.13	0.80
-1.20	0.10	27.53	0.00	0.00	0.00	0.11	0.77
-1.10	0.09	27.55	0.00	0.00	0.00	0.09	0.72
-1.00	0.08	27.58	0.00	0.00	0.00	0.05	0.66
-0.90	0.07	27.59	0.00	0.00	0.00	0.03	0.63
-0.80	0.06	27.62	0.00	0.00	0.00	0.00	0.57
-0.70	0.06	27.64	0.00	0.00	0.00	0.00	0.54
-0.60	0.05	27.66	0.00	0.00	0.00	0.00	0.50
-0.50	0.04	27.68	0.00	0.00	0.00	0.00	0.47
-0.40	0.04	27.70	0.00	0.00	0.00	0.00	0.42
-0.30	0.03	27.72	0.00	0.00	0.00	0.00	0.40
-0.20	0.03	27.73	0.00	0.00	0.00	0.00	0.37
-0.10	0.03	27.76	0.00	0.00	0.00	0.00	0.34
0.00	0.03	27.77	0.00	0.00	0.00	0.00	0.32
0.10	0.02	27.80	0.00	0.00	0.00	0.00	0.31
0.20	0.02	27.81	0.00	0.00	0.00	0.00	0.29
0.30	0.02	27.83	0.00	0.00	0.00	0.00	0.27
0.40	0.02	27.85	0.00	0.00	0.00	0.00	0.26
0.50	0.02	27.88	0.00	0.00	0.00	0.00	0.26
0.60	0.02	27.90	0.00	0.00	0.00	0.00	0.26
0.70	0.02	27.92	0.00	0.00	0.00	0.00	0.25
0.80	0.02	27.94	0.00	0.00	0.00	0.00	0.25
0.90	0.02	27.96	0.00	0.00	0.00	0.00	0.26
1.00	0.02	27.98	0.00	0.00	0.00	0.00	0.27
1.10	0.02	28.00	0.00	0.00	0.00	0.00	0.28
1.20	0.02	28.02	0.00	0.00	0.00	0.00	0.30
1.30	0.02	28.03	0.00	0.00	0.00	0.00	0.30
1.40	0.02	28.05	0.00	0.00	0.00	0.00	0.32
1.50	0.02	28.07	0.00	0.00	0.00	0.00	0.34
1.60	0.02	28.10	0.00	0.00	0.00	0.00	0.35
1.70	0.03	28.11	0.00	0.00	0.00	0.00	0.37
1.80	0.03	28.14	0.00	0.00	0.00	0.00	0.40
1.90	0.03	28.15	0.00	0.00	0.00	0.00	0.43
2.00	0.03	28.17	0.00	0.00	0.00	0.00	0.44

Table 99: Put option prices for May Nino 3.4 SST conditioned on IRI ensemble forecasts released in September

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.27	27.28	0.00	0.00	0.03	0.49	1.00
-1.90	0.25	27.30	0.00	0.00	0.00	0.45	1.00
-1.80	0.24	27.33	0.00	0.00	0.00	0.42	1.00
-1.70	0.22	27.35	0.00	0.00	0.00	0.39	1.00
-1.60	0.21	27.37	0.00	0.00	0.00	0.35	1.00
-1.50	0.19	27.40	0.00	0.00	0.00	0.32	1.00
-1.40	0.17	27.42	0.00	0.00	0.00	0.28	1.00
-1.30	0.16	27.45	0.00	0.00	0.00	0.24	1.00
-1.20	0.14	27.47	0.00	0.00	0.00	0.20	0.96
-1.10	0.13	27.49	0.00	0.00	0.00	0.17	0.88
-1.00	0.12	27.52	0.00	0.00	0.00	0.14	0.83
-0.90	0.10	27.54	0.00	0.00	0.00	0.10	0.75
-0.80	0.09	27.57	0.00	0.00	0.00	0.07	0.70
-0.70	0.08	27.59	0.00	0.00	0.00	0.04	0.64
-0.60	0.07	27.61	0.00	0.00	0.00	0.01	0.59
-0.50	0.06	27.64	0.00	0.00	0.00	0.00	0.53
-0.40	0.05	27.67	0.00	0.00	0.00	0.00	0.47
-0.30	0.04	27.69	0.00	0.00	0.00	0.00	0.43
-0.20	0.03	27.71	0.00	0.00	0.00	0.00	0.40
-0.10	0.03	27.74	0.00	0.00	0.00	0.00	0.37
0.00	0.03	27.76	0.00	0.00	0.00	0.00	0.33
0.10	0.02	27.79	0.00	0.00	0.00	0.00	0.31
0.20	0.02	27.81	0.00	0.00	0.00	0.00	0.29
0.30	0.02	27.83	0.00	0.00	0.00	0.00	0.27
0.40	0.02	27.86	0.00	0.00	0.00	0.00	0.26
0.50	0.02	27.88	0.00	0.00	0.00	0.00	0.26
0.60	0.02	27.90	0.00	0.00	0.00	0.00	0.26
0.70	0.02	27.93	0.00	0.00	0.00	0.00	0.27
0.80	0.02	27.95	0.00	0.00	0.00	0.00	0.28
0.90	0.02	27.98	0.00	0.00	0.00	0.00	0.27
1.00	0.02	28.01	0.00	0.00	0.00	0.00	0.30
1.10	0.02	28.03	0.00	0.00	0.00	0.00	0.33
1.20	0.02	28.05	0.00	0.00	0.00	0.00	0.34
1.30	0.02	28.07	0.00	0.00	0.00	0.00	0.36
1.40	0.03	28.10	0.00	0.00	0.00	0.00	0.38
1.50	0.03	28.12	0.00	0.00	0.00	0.00	0.41
1.60	0.03	28.15	0.00	0.00	0.00	0.00	0.43
1.70	0.03	28.17	0.00	0.00	0.00	0.00	0.49
1.80	0.03	28.20	0.00	0.00	0.00	0.00	0.49
1.90	0.04	28.22	0.00	0.00	0.00	0.00	0.53
2.00	0.04	28.24	0.00	0.00	0.00	0.00	0.56

Table 100: Put option prices for May Nino 3.4 SST conditioned on IRI ensemble forecasts released in August

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.22	27.41	0.00	0.00	0.00	0.38	1.00
-1.90	0.21	27.42	0.00	0.00	0.00	0.35	1.00
-1.80	0.20	27.44	0.00	0.00	0.00	0.32	1.00
-1.70	0.18	27.46	0.00	0.00	0.00	0.29	1.00
-1.60	0.17	27.48	0.00	0.00	0.00	0.26	1.00
-1.50	0.16	27.50	0.00	0.00	0.00	0.23	1.00
-1.40	0.15	27.52	0.00	0.00	0.00	0.20	1.00
-1.30	0.13	27.53	0.00	0.00	0.00	0.16	0.94
-1.20	0.12	27.55	0.00	0.00	0.00	0.14	0.87
-1.10	0.11	27.57	0.00	0.00	0.00	0.11	0.82
-1.00	0.10	27.59	0.00	0.00	0.00	0.08	0.76
-0.90	0.09	27.61	0.00	0.00	0.00	0.05	0.70
-0.80	0.08	27.62	0.00	0.00	0.00	0.02	0.65
-0.70	0.07	27.64	0.00	0.00	0.00	0.00	0.61
-0.60	0.06	27.66	0.00	0.00	0.00	0.00	0.54
-0.50	0.05	27.68	0.00	0.00	0.00	0.00	0.51
-0.40	0.05	27.70	0.00	0.00	0.00	0.00	0.48
-0.30	0.04	27.72	0.00	0.00	0.00	0.00	0.42
-0.20	0.03	27.73	0.00	0.00	0.00	0.00	0.39
-0.10	0.03	27.75	0.00	0.00	0.00	0.00	0.36
0.00	0.03	27.77	0.00	0.00	0.00	0.00	0.34
0.10	0.02	27.79	0.00	0.00	0.00	0.00	0.32
0.20	0.02	27.80	0.00	0.00	0.00	0.00	0.31
0.30	0.02	27.82	0.00	0.00	0.00	0.00	0.30
0.40	0.02	27.84	0.00	0.00	0.00	0.00	0.28
0.50	0.02	27.86	0.00	0.00	0.00	0.00	0.29
0.60	0.02	27.88	0.00	0.00	0.00	0.00	0.29
0.70	0.02	27.90	0.00	0.00	0.00	0.00	0.30
0.80	0.02	27.92	0.00	0.00	0.00	0.00	0.31
0.90	0.02	27.94	0.00	0.00	0.00	0.00	0.33
1.00	0.02	27.95	0.00	0.00	0.00	0.00	0.35
1.10	0.03	27.97	0.00	0.00	0.00	0.00	0.37
1.20	0.03	27.99	0.00	0.00	0.00	0.00	0.39
1.30	0.03	28.01	0.00	0.00	0.00	0.00	0.43
1.40	0.03	28.03	0.00	0.00	0.00	0.00	0.45
1.50	0.03	28.04	0.00	0.00	0.00	0.00	0.48
1.60	0.04	28.06	0.00	0.00	0.00	0.00	0.51
1.70	0.04	28.08	0.00	0.00	0.00	0.00	0.55
1.80	0.04	28.10	0.00	0.00	0.00	0.00	0.58
1.90	0.05	28.12	0.00	0.00	0.00	0.00	0.61
2.00	0.05	28.13	0.00	0.00	0.00	0.00	0.65

Table 101: Put option prices for May Nino 3.4 SST conditioned on IRI ensemble forecasts released in July

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.15	27.67	0.00	0.00	0.00	0.17	1.00
-1.90	0.14	27.68	0.00	0.00	0.00	0.15	1.00
-1.80	0.13	27.68	0.00	0.00	0.00	0.13	1.00
-1.70	0.13	27.68	0.00	0.00	0.00	0.11	1.00
-1.60	0.12	27.69	0.00	0.00	0.00	0.09	0.98
-1.50	0.11	27.69	0.00	0.00	0.00	0.07	0.93
-1.40	0.10	27.69	0.00	0.00	0.00	0.04	0.88
-1.30	0.09	27.70	0.00	0.00	0.00	0.03	0.82
-1.20	0.08	27.70	0.00	0.00	0.00	0.01	0.76
-1.10	0.08	27.71	0.00	0.00	0.00	0.00	0.71
-1.00	0.07	27.71	0.00	0.00	0.00	0.00	0.66
-0.90	0.06	27.71	0.00	0.00	0.00	0.00	0.61
-0.80	0.06	27.72	0.00	0.00	0.00	0.00	0.56
-0.70	0.05	27.72	0.00	0.00	0.00	0.00	0.53
-0.60	0.05	27.72	0.00	0.00	0.00	0.00	0.49
-0.50	0.04	27.73	0.00	0.00	0.00	0.00	0.44
-0.40	0.04	27.73	0.00	0.00	0.00	0.00	0.43
-0.30	0.03	27.73	0.00	0.00	0.00	0.00	0.39
-0.20	0.03	27.74	0.00	0.00	0.00	0.00	0.37
-0.10	0.03	27.74	0.00	0.00	0.00	0.00	0.34
0.00	0.03	27.75	0.00	0.00	0.00	0.00	0.32
0.10	0.03	27.75	0.00	0.00	0.00	0.00	0.32
0.20	0.02	27.75	0.00	0.00	0.00	0.00	0.31
0.30	0.03	27.76	0.00	0.00	0.00	0.00	0.33
0.40	0.03	27.76	0.00	0.00	0.00	0.00	0.33
0.50	0.03	27.76	0.00	0.00	0.00	0.00	0.35
0.60	0.03	27.77	0.00	0.00	0.00	0.00	0.36
0.70	0.03	27.77	0.00	0.00	0.00	0.00	0.40
0.80	0.03	27.78	0.00	0.00	0.00	0.00	0.42
0.90	0.04	27.78	0.00	0.00	0.00	0.00	0.46
1.00	0.04	27.79	0.00	0.00	0.00	0.00	0.49
1.10	0.05	27.79	0.00	0.00	0.00	0.00	0.53
1.20	0.05	27.79	0.00	0.00	0.00	0.00	0.58
1.30	0.06	27.79	0.00	0.00	0.00	0.00	0.62
1.40	0.06	27.79	0.00	0.00	0.00	0.00	0.66
1.50	0.07	27.80	0.00	0.00	0.00	0.00	0.71
1.60	0.07	27.80	0.00	0.00	0.00	0.00	0.76
1.70	0.08	27.81	0.00	0.00	0.00	0.00	0.81
1.80	0.09	27.81	0.00	0.00	0.00	0.00	0.87
1.90	0.09	27.82	0.00	0.00	0.00	0.00	0.91
2.00	0.10	27.82	0.00	0.00	0.00	0.00	0.96

Appendix I: June Pricing

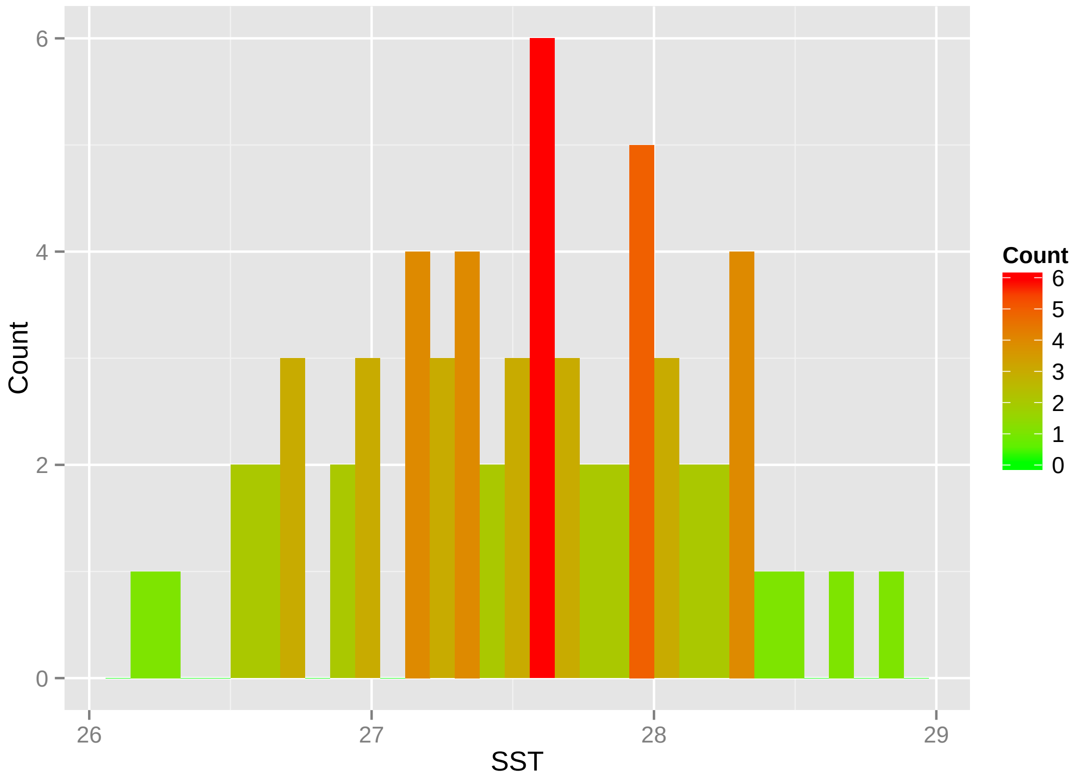


Figure 63: Histogram of June SST for Niño 3.4 ERSST.3b

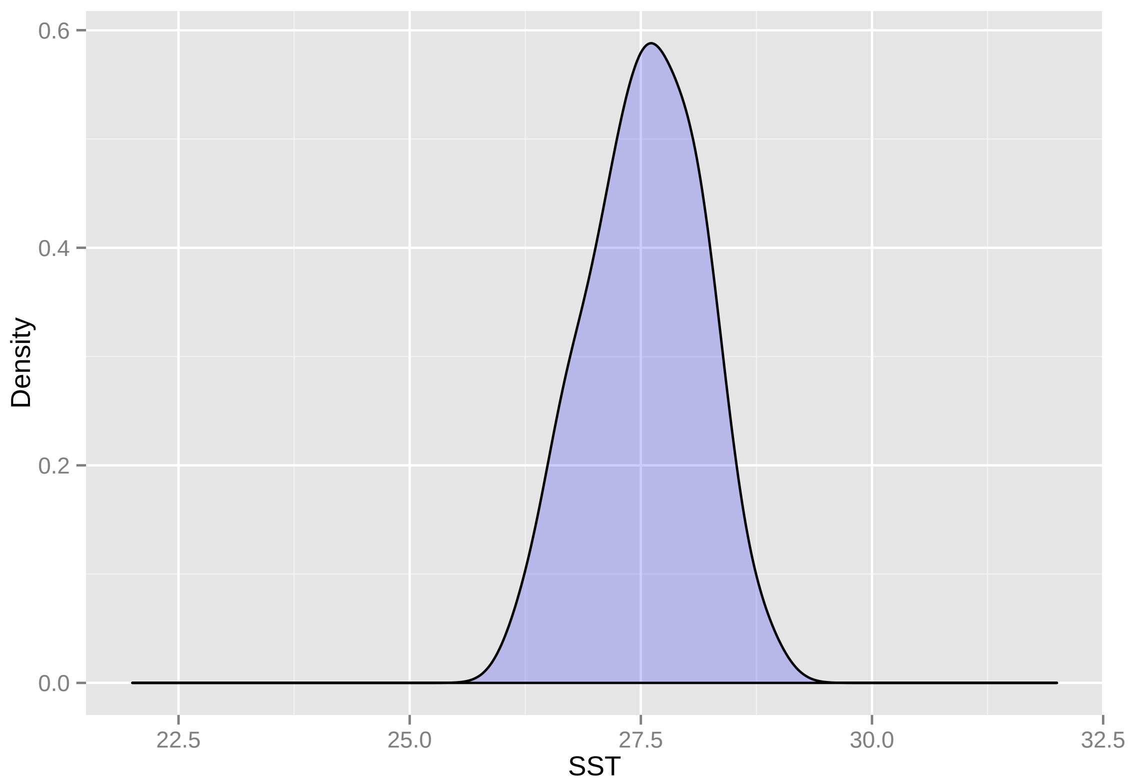


Figure 64: Kernel density estimate of June SST for Niño 3.4 ERSST.3b

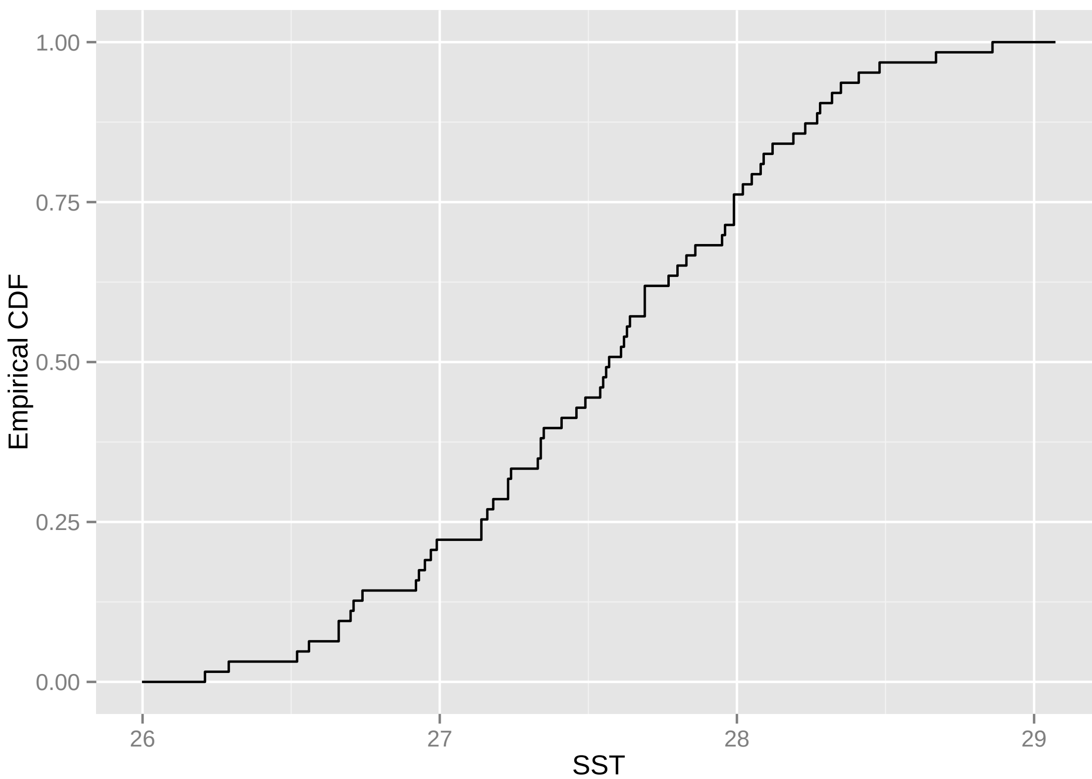


Figure 65: ECDF of June SST for Niño 3.4 ERSST.3b

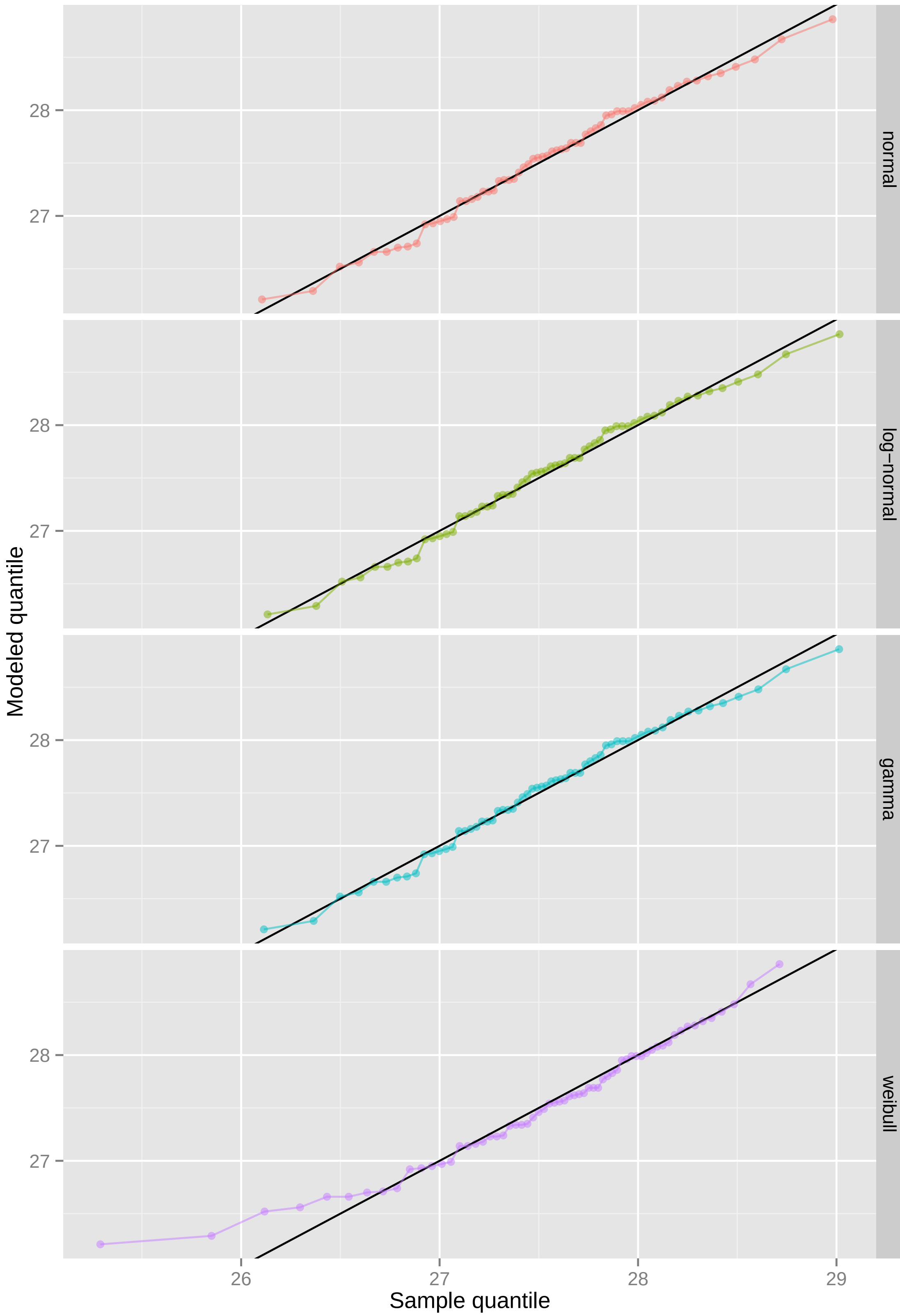


Figure 66: QQ plots of June SST for Niño 3.4 ERSST.3b compared to samples from various distributions (n=2 million)

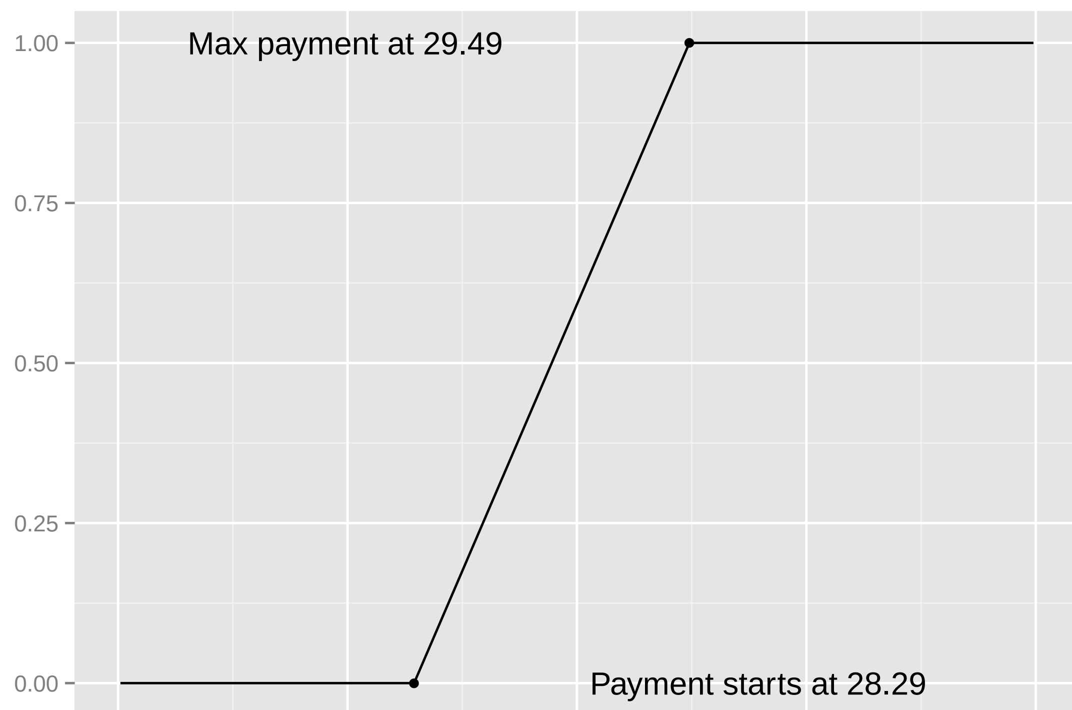


Figure 67: Payout function for call option on June SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations above the baseline

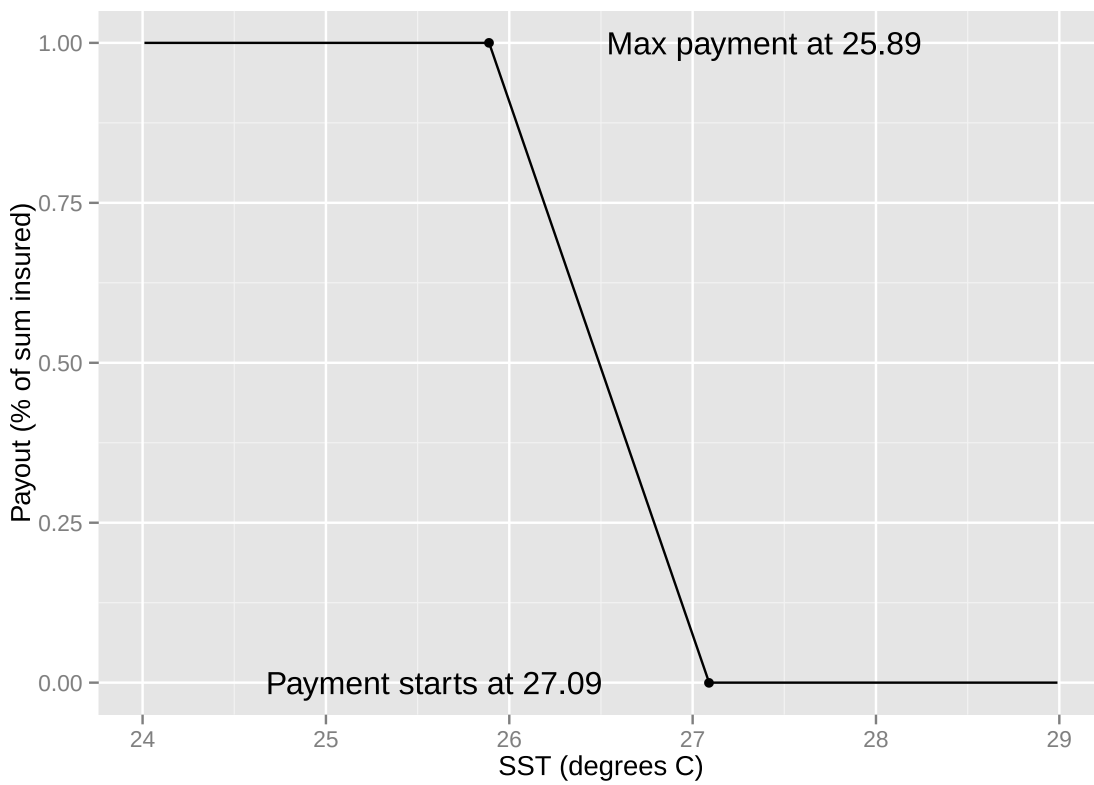


Figure 68: Payout function for put option on June SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

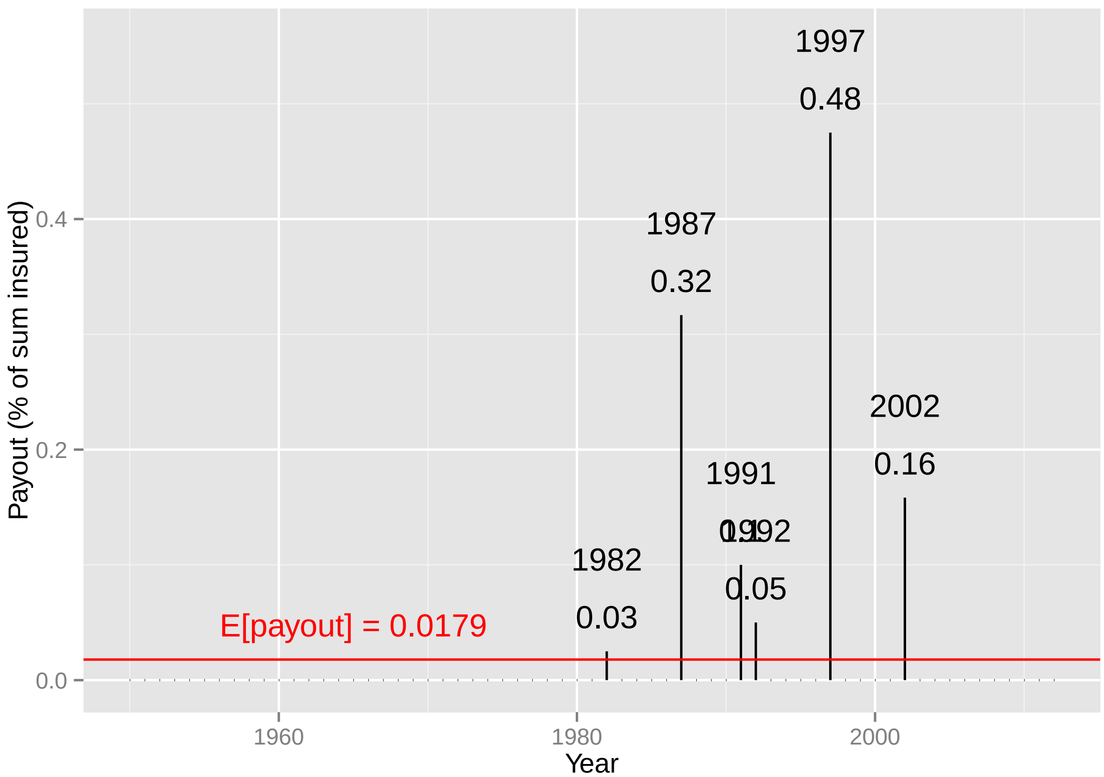


Figure 69: Historical burn on call option for June SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations above the baseline

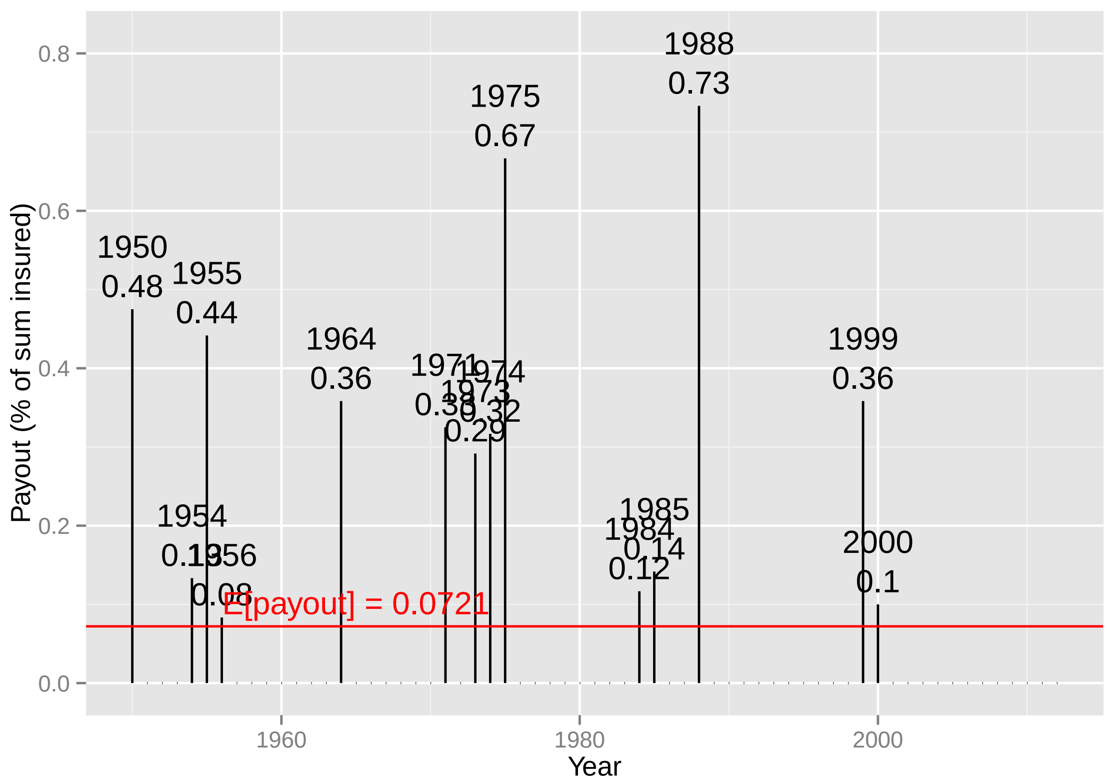


Figure 70: Historical burn on put option on June SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

Table 102: Bayesian regression linking June Niño 3.4 SST anomalies to average of relevant IRI ensemble forecasts

	mean	sd	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q	n_eff	Rhat
April forecast average covering June Niño 3.4 SST anomalies									
α	0.10	0.10	-0.10	0.00	0.10	0.10	0.30	104994	1
β	0.90	0.40	0.20	0.70	0.90	1.10	1.60	97256	1
σ_y^2	0.10	0.10	0.00	0.10	0.10	0.10	0.30	56215	1
March forecast average covering June Niño 3.4 SST anomalies									
α	0.00	0.10	-0.20	0.00	0.00	0.10	0.30	106603	1
β	0.70	0.30	0.00	0.50	0.70	0.90	1.40	96144	1
σ_y^2	0.10	0.10	0.10	0.10	0.10	0.20	0.30	57011	1
February forecast average covering June Niño 3.4 SST anomalies									
α	0.00	0.10	-0.30	-0.10	0.00	0.00	0.20	96984	1
β	0.30	0.30	-0.30	0.10	0.30	0.50	1.00	89398	1
σ_y^2	0.10	0.10	0.00	0.10	0.10	0.20	0.40	54345	1
January forecast average covering June Niño 3.4 SST anomalies									
α	0.00	0.10	-0.20	-0.10	0.00	0.00	0.20	100924	1
β	0.20	0.30	-0.40	0.00	0.20	0.30	0.80	91794	1
σ_y^2	0.10	0.10	0.00	0.10	0.10	0.20	0.40	59032	1
December forecast average covering June Niño 3.4 SST anomalies									
α	0.00	0.10	-0.20	-0.10	0.00	0.10	0.20	94181	1
β	0.10	0.30	-0.50	-0.10	0.10	0.30	0.70	92806	1
σ_y^2	0.10	0.10	0.10	0.10	0.10	0.20	0.40	55672	1
November forecast average covering June Niño 3.4 SST anomalies									
α	0.00	0.10	-0.20	-0.10	0.00	0.10	0.20	90271	1
β	0.00	0.30	-0.70	-0.20	0.00	0.20	0.60	87422	1
σ_y^2	0.10	0.10	0.10	0.10	0.10	0.20	0.40	57269	1
October forecast average covering June Niño 3.4 SST anomalies									
α	0.00	0.10	-0.30	-0.10	0.00	0.10	0.20	89237	1
β	0.00	0.40	-0.70	-0.20	0.00	0.20	0.70	82520	1
σ_y^2	0.10	0.10	0.10	0.10	0.10	0.20	0.40	55985	1
September forecast average covering June Niño 3.4 SST anomalies									
α	0.00	0.10	-0.30	-0.10	0.00	0.10	0.20	79106	1
β	0.00	0.40	-0.80	-0.20	0.00	0.30	0.80	77953	1
σ_y^2	0.10	0.10	0.10	0.10	0.10	0.20	0.40	55038	1
August forecast average covering June Niño 3.4 SST anomalies									
α	0.00	0.10	-0.30	-0.10	0.00	0.10	0.30	77689	1
β	0.00	0.40	-0.80	-0.30	0.00	0.20	0.70	78478	1
σ_y^2	0.10	0.10	0.10	0.10	0.10	0.20	0.40	55855	1

Table 103: Call option prices for June Nino 3.4 SST conditioned on IRI ensemble forecasts released in April

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	25.98	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	26.07	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	26.15	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	26.25	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	26.33	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	26.42	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	26.51	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	26.60	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	26.69	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	26.78	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	26.87	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	26.95	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	27.04	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	27.13	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	27.22	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	27.31	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	27.40	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	27.49	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	27.58	0.00	0.00	0.00	0.00	0.01
-0.10	0.01	27.66	0.00	0.00	0.00	0.00	0.06
0.00	0.01	27.75	0.00	0.00	0.00	0.00	0.13
0.10	0.01	27.84	0.00	0.00	0.00	0.00	0.21
0.20	0.02	27.92	0.00	0.00	0.00	0.00	0.29
0.30	0.04	28.01	0.00	0.00	0.00	0.00	0.37
0.40	0.06	28.10	0.00	0.00	0.00	0.04	0.48
0.50	0.09	28.19	0.00	0.00	0.00	0.12	0.57
0.60	0.13	28.28	0.00	0.00	0.00	0.20	0.67
0.70	0.17	28.37	0.00	0.00	0.07	0.29	0.78
0.80	0.22	28.46	0.00	0.00	0.14	0.37	0.89
0.90	0.28	28.55	0.00	0.00	0.21	0.46	1.00
1.00	0.34	28.63	0.00	0.03	0.29	0.54	1.00
1.10	0.39	28.72	0.00	0.09	0.36	0.63	1.00
1.20	0.45	28.81	0.00	0.15	0.43	0.72	1.00
1.30	0.50	28.90	0.00	0.21	0.51	0.81	1.00
1.40	0.56	28.99	0.00	0.27	0.58	0.90	1.00
1.50	0.60	29.07	0.00	0.33	0.65	0.98	1.00
1.60	0.65	29.16	0.00	0.38	0.73	1.00	1.00
1.70	0.69	29.25	0.00	0.44	0.80	1.00	1.00
1.80	0.72	29.34	0.00	0.50	0.88	1.00	1.00
1.90	0.75	29.43	0.00	0.56	0.95	1.00	1.00
2.00	0.78	29.52	0.00	0.61	1.00	1.00	1.00

Table 104: Call option prices for June Nino 3.4 SST conditioned on IRI ensemble forecasts released in March

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	26.36	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	26.43	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	26.50	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	26.56	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	26.63	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	26.70	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	26.77	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	26.84	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	26.91	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	26.98	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	27.05	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	27.11	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	27.19	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	27.26	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	27.32	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	27.39	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	27.46	0.00	0.00	0.00	0.00	0.00
-0.30	0.01	27.53	0.00	0.00	0.00	0.00	0.03
-0.20	0.01	27.60	0.00	0.00	0.00	0.00	0.07
-0.10	0.01	27.67	0.00	0.00	0.00	0.00	0.12
0.00	0.01	27.74	0.00	0.00	0.00	0.00	0.18
0.10	0.02	27.81	0.00	0.00	0.00	0.00	0.23
0.20	0.02	27.88	0.00	0.00	0.00	0.00	0.30
0.30	0.03	27.94	0.00	0.00	0.00	0.00	0.37
0.40	0.05	28.01	0.00	0.00	0.00	0.00	0.45
0.50	0.07	28.09	0.00	0.00	0.00	0.05	0.51
0.60	0.09	28.16	0.00	0.00	0.00	0.11	0.61
0.70	0.12	28.22	0.00	0.00	0.00	0.18	0.69
0.80	0.15	28.29	0.00	0.00	0.00	0.25	0.77
0.90	0.19	28.36	0.00	0.00	0.06	0.32	0.88
1.00	0.23	28.43	0.00	0.00	0.12	0.38	0.97
1.10	0.27	28.50	0.00	0.00	0.17	0.45	1.00
1.20	0.31	28.57	0.00	0.00	0.23	0.53	1.00
1.30	0.35	28.64	0.00	0.00	0.29	0.60	1.00
1.40	0.39	28.71	0.00	0.03	0.35	0.67	1.00
1.50	0.44	28.78	0.00	0.08	0.41	0.74	1.00
1.60	0.48	28.85	0.00	0.11	0.46	0.81	1.00
1.70	0.52	28.92	0.00	0.16	0.52	0.89	1.00
1.80	0.55	28.99	0.00	0.20	0.58	0.96	1.00
1.90	0.58	29.05	0.00	0.24	0.64	1.00	1.00
2.00	0.61	29.12	0.00	0.28	0.69	1.00	1.00

Table 105: Call option prices for June Nino 3.4 SST conditioned on IRI ensemble forecasts released in February

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.02	26.97	0.00	0.00	0.00	0.00	0.22
-1.90	0.02	27.01	0.00	0.00	0.00	0.00	0.21
-1.80	0.01	27.04	0.00	0.00	0.00	0.00	0.18
-1.70	0.01	27.08	0.00	0.00	0.00	0.00	0.17
-1.60	0.01	27.11	0.00	0.00	0.00	0.00	0.16
-1.50	0.01	27.14	0.00	0.00	0.00	0.00	0.14
-1.40	0.01	27.18	0.00	0.00	0.00	0.00	0.12
-1.30	0.01	27.21	0.00	0.00	0.00	0.00	0.09
-1.20	0.01	27.24	0.00	0.00	0.00	0.00	0.09
-1.10	0.01	27.27	0.00	0.00	0.00	0.00	0.08
-1.00	0.01	27.31	0.00	0.00	0.00	0.00	0.08
-0.90	0.01	27.34	0.00	0.00	0.00	0.00	0.06
-0.80	0.01	27.38	0.00	0.00	0.00	0.00	0.06
-0.70	0.01	27.41	0.00	0.00	0.00	0.00	0.06
-0.60	0.01	27.44	0.00	0.00	0.00	0.00	0.05
-0.50	0.01	27.47	0.00	0.00	0.00	0.00	0.06
-0.40	0.01	27.51	0.00	0.00	0.00	0.00	0.05
-0.30	0.01	27.54	0.00	0.00	0.00	0.00	0.08
-0.20	0.01	27.58	0.00	0.00	0.00	0.00	0.08
-0.10	0.01	27.61	0.00	0.00	0.00	0.00	0.10
0.00	0.01	27.64	0.00	0.00	0.00	0.00	0.13
0.10	0.01	27.68	0.00	0.00	0.00	0.00	0.15
0.20	0.01	27.71	0.00	0.00	0.00	0.00	0.18
0.30	0.02	27.74	0.00	0.00	0.00	0.00	0.23
0.40	0.02	27.78	0.00	0.00	0.00	0.00	0.26
0.50	0.02	27.81	0.00	0.00	0.00	0.00	0.31
0.60	0.03	27.84	0.00	0.00	0.00	0.00	0.35
0.70	0.04	27.88	0.00	0.00	0.00	0.00	0.41
0.80	0.04	27.91	0.00	0.00	0.00	0.00	0.46
0.90	0.05	27.95	0.00	0.00	0.00	0.00	0.53
1.00	0.06	27.98	0.00	0.00	0.00	0.00	0.59
1.10	0.08	28.01	0.00	0.00	0.00	0.04	0.65
1.20	0.09	28.04	0.00	0.00	0.00	0.07	0.71
1.30	0.11	28.08	0.00	0.00	0.00	0.11	0.77
1.40	0.12	28.11	0.00	0.00	0.00	0.15	0.85
1.50	0.14	28.15	0.00	0.00	0.00	0.20	0.92
1.60	0.16	28.18	0.00	0.00	0.00	0.24	0.99
1.70	0.17	28.21	0.00	0.00	0.00	0.28	1.00
1.80	0.19	28.25	0.00	0.00	0.00	0.32	1.00
1.90	0.21	28.28	0.00	0.00	0.00	0.36	1.00
2.00	0.23	28.31	0.00	0.00	0.02	0.41	1.00

Table 106: Call option prices for June Nino 3.4 SST conditioned on IRI ensemble forecasts released in January

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.03	27.33	0.00	0.00	0.00	0.00	0.42
-1.90	0.03	27.35	0.00	0.00	0.00	0.00	0.38
-1.80	0.02	27.37	0.00	0.00	0.00	0.00	0.35
-1.70	0.02	27.39	0.00	0.00	0.00	0.00	0.33
-1.60	0.02	27.40	0.00	0.00	0.00	0.00	0.31
-1.50	0.02	27.42	0.00	0.00	0.00	0.00	0.29
-1.40	0.02	27.44	0.00	0.00	0.00	0.00	0.27
-1.30	0.02	27.45	0.00	0.00	0.00	0.00	0.24
-1.20	0.02	27.47	0.00	0.00	0.00	0.00	0.22
-1.10	0.01	27.48	0.00	0.00	0.00	0.00	0.20
-1.00	0.01	27.50	0.00	0.00	0.00	0.00	0.19
-0.90	0.01	27.52	0.00	0.00	0.00	0.00	0.16
-0.80	0.01	27.54	0.00	0.00	0.00	0.00	0.15
-0.70	0.01	27.55	0.00	0.00	0.00	0.00	0.13
-0.60	0.01	27.57	0.00	0.00	0.00	0.00	0.14
-0.50	0.01	27.59	0.00	0.00	0.00	0.00	0.12
-0.40	0.01	27.60	0.00	0.00	0.00	0.00	0.12
-0.30	0.01	27.62	0.00	0.00	0.00	0.00	0.13
-0.20	0.01	27.64	0.00	0.00	0.00	0.00	0.12
-0.10	0.01	27.65	0.00	0.00	0.00	0.00	0.14
0.00	0.01	27.67	0.00	0.00	0.00	0.00	0.14
0.10	0.01	27.68	0.00	0.00	0.00	0.00	0.15
0.20	0.01	27.70	0.00	0.00	0.00	0.00	0.17
0.30	0.01	27.72	0.00	0.00	0.00	0.00	0.19
0.40	0.01	27.74	0.00	0.00	0.00	0.00	0.22
0.50	0.02	27.75	0.00	0.00	0.00	0.00	0.24
0.60	0.02	27.77	0.00	0.00	0.00	0.00	0.28
0.70	0.02	27.78	0.00	0.00	0.00	0.00	0.30
0.80	0.03	27.80	0.00	0.00	0.00	0.00	0.34
0.90	0.03	27.82	0.00	0.00	0.00	0.00	0.39
1.00	0.04	27.84	0.00	0.00	0.00	0.00	0.44
1.10	0.04	27.85	0.00	0.00	0.00	0.00	0.47
1.20	0.05	27.87	0.00	0.00	0.00	0.00	0.53
1.30	0.06	27.88	0.00	0.00	0.00	0.00	0.56
1.40	0.06	27.90	0.00	0.00	0.00	0.00	0.60
1.50	0.07	27.92	0.00	0.00	0.00	0.00	0.67
1.60	0.08	27.93	0.00	0.00	0.00	0.01	0.72
1.70	0.09	27.95	0.00	0.00	0.00	0.04	0.77
1.80	0.10	27.96	0.00	0.00	0.00	0.06	0.81
1.90	0.11	27.98	0.00	0.00	0.00	0.09	0.88
2.00	0.12	28.00	0.00	0.00	0.00	0.12	0.94

Table 107: Call option prices for June Nino 3.4 SST conditioned on IRI ensemble forecasts released in December

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.04	27.50	0.00	0.00	0.00	0.00	0.57
-1.90	0.04	27.51	0.00	0.00	0.00	0.00	0.52
-1.80	0.04	27.52	0.00	0.00	0.00	0.00	0.52
-1.70	0.03	27.52	0.00	0.00	0.00	0.00	0.47
-1.60	0.03	27.53	0.00	0.00	0.00	0.00	0.44
-1.50	0.03	27.54	0.00	0.00	0.00	0.00	0.41
-1.40	0.03	27.55	0.00	0.00	0.00	0.00	0.38
-1.30	0.02	27.56	0.00	0.00	0.00	0.00	0.35
-1.20	0.02	27.57	0.00	0.00	0.00	0.00	0.32
-1.10	0.02	27.58	0.00	0.00	0.00	0.00	0.29
-1.00	0.02	27.58	0.00	0.00	0.00	0.00	0.27
-0.90	0.02	27.59	0.00	0.00	0.00	0.00	0.26
-0.80	0.02	27.60	0.00	0.00	0.00	0.00	0.23
-0.70	0.01	27.61	0.00	0.00	0.00	0.00	0.21
-0.60	0.01	27.62	0.00	0.00	0.00	0.00	0.19
-0.50	0.01	27.63	0.00	0.00	0.00	0.00	0.17
-0.40	0.01	27.64	0.00	0.00	0.00	0.00	0.17
-0.30	0.01	27.65	0.00	0.00	0.00	0.00	0.15
-0.20	0.01	27.66	0.00	0.00	0.00	0.00	0.16
-0.10	0.01	27.66	0.00	0.00	0.00	0.00	0.16
0.00	0.01	27.67	0.00	0.00	0.00	0.00	0.16
0.10	0.01	27.68	0.00	0.00	0.00	0.00	0.17
0.20	0.01	27.69	0.00	0.00	0.00	0.00	0.17
0.30	0.01	27.69	0.00	0.00	0.00	0.00	0.18
0.40	0.01	27.71	0.00	0.00	0.00	0.00	0.20
0.50	0.02	27.71	0.00	0.00	0.00	0.00	0.22
0.60	0.02	27.72	0.00	0.00	0.00	0.00	0.24
0.70	0.02	27.73	0.00	0.00	0.00	0.00	0.26
0.80	0.02	27.74	0.00	0.00	0.00	0.00	0.30
0.90	0.02	27.75	0.00	0.00	0.00	0.00	0.33
1.00	0.03	27.75	0.00	0.00	0.00	0.00	0.36
1.10	0.03	27.77	0.00	0.00	0.00	0.00	0.41
1.20	0.04	27.77	0.00	0.00	0.00	0.00	0.43
1.30	0.04	27.78	0.00	0.00	0.00	0.00	0.47
1.40	0.04	27.79	0.00	0.00	0.00	0.00	0.51
1.50	0.05	27.80	0.00	0.00	0.00	0.00	0.56
1.60	0.06	27.81	0.00	0.00	0.00	0.00	0.61
1.70	0.06	27.82	0.00	0.00	0.00	0.00	0.65
1.80	0.07	27.83	0.00	0.00	0.00	0.00	0.70
1.90	0.07	27.83	0.00	0.00	0.00	0.00	0.74
2.00	0.08	27.84	0.00	0.00	0.00	0.00	0.80

Table 108: Call option prices for June Nino 3.4 SST conditioned on IRI ensemble forecasts released in November

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.09	27.78	0.00	0.00	0.00	0.00	0.91
-1.90	0.09	27.77	0.00	0.00	0.00	0.00	0.85
-1.80	0.08	27.77	0.00	0.00	0.00	0.00	0.82
-1.70	0.07	27.76	0.00	0.00	0.00	0.00	0.77
-1.60	0.07	27.76	0.00	0.00	0.00	0.00	0.71
-1.50	0.06	27.76	0.00	0.00	0.00	0.00	0.66
-1.40	0.06	27.75	0.00	0.00	0.00	0.00	0.61
-1.30	0.05	27.75	0.00	0.00	0.00	0.00	0.58
-1.20	0.05	27.74	0.00	0.00	0.00	0.00	0.54
-1.10	0.04	27.74	0.00	0.00	0.00	0.00	0.50
-1.00	0.04	27.73	0.00	0.00	0.00	0.00	0.46
-0.90	0.03	27.72	0.00	0.00	0.00	0.00	0.40
-0.80	0.03	27.72	0.00	0.00	0.00	0.00	0.37
-0.70	0.02	27.72	0.00	0.00	0.00	0.00	0.33
-0.60	0.02	27.71	0.00	0.00	0.00	0.00	0.31
-0.50	0.02	27.71	0.00	0.00	0.00	0.00	0.27
-0.40	0.02	27.70	0.00	0.00	0.00	0.00	0.25
-0.30	0.02	27.70	0.00	0.00	0.00	0.00	0.23
-0.20	0.01	27.69	0.00	0.00	0.00	0.00	0.20
-0.10	0.01	27.69	0.00	0.00	0.00	0.00	0.17
0.00	0.01	27.68	0.00	0.00	0.00	0.00	0.17
0.10	0.01	27.68	0.00	0.00	0.00	0.00	0.15
0.20	0.01	27.67	0.00	0.00	0.00	0.00	0.15
0.30	0.01	27.66	0.00	0.00	0.00	0.00	0.15
0.40	0.01	27.66	0.00	0.00	0.00	0.00	0.17
0.50	0.01	27.66	0.00	0.00	0.00	0.00	0.18
0.60	0.01	27.65	0.00	0.00	0.00	0.00	0.19
0.70	0.01	27.65	0.00	0.00	0.00	0.00	0.21
0.80	0.02	27.65	0.00	0.00	0.00	0.00	0.23
0.90	0.02	27.64	0.00	0.00	0.00	0.00	0.24
1.00	0.02	27.63	0.00	0.00	0.00	0.00	0.26
1.10	0.02	27.63	0.00	0.00	0.00	0.00	0.30
1.20	0.02	27.63	0.00	0.00	0.00	0.00	0.33
1.30	0.03	27.62	0.00	0.00	0.00	0.00	0.35
1.40	0.03	27.61	0.00	0.00	0.00	0.00	0.38
1.50	0.03	27.61	0.00	0.00	0.00	0.00	0.43
1.60	0.03	27.60	0.00	0.00	0.00	0.00	0.46
1.70	0.04	27.60	0.00	0.00	0.00	0.00	0.50
1.80	0.04	27.59	0.00	0.00	0.00	0.00	0.54
1.90	0.05	27.59	0.00	0.00	0.00	0.00	0.58
2.00	0.05	27.59	0.00	0.00	0.00	0.00	0.62

Table 109: Call option prices for June Nino 3.4 SST conditioned on IRI ensemble forecasts released in October

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.09	27.73	0.00	0.00	0.00	0.00	0.95
-1.90	0.09	27.72	0.00	0.00	0.00	0.00	0.90
-1.80	0.08	27.72	0.00	0.00	0.00	0.00	0.83
-1.70	0.07	27.71	0.00	0.00	0.00	0.00	0.80
-1.60	0.07	27.71	0.00	0.00	0.00	0.00	0.73
-1.50	0.06	27.71	0.00	0.00	0.00	0.00	0.69
-1.40	0.06	27.71	0.00	0.00	0.00	0.00	0.64
-1.30	0.05	27.71	0.00	0.00	0.00	0.00	0.59
-1.20	0.04	27.71	0.00	0.00	0.00	0.00	0.54
-1.10	0.04	27.71	0.00	0.00	0.00	0.00	0.51
-1.00	0.04	27.70	0.00	0.00	0.00	0.00	0.46
-0.90	0.03	27.70	0.00	0.00	0.00	0.00	0.41
-0.80	0.03	27.70	0.00	0.00	0.00	0.00	0.38
-0.70	0.02	27.69	0.00	0.00	0.00	0.00	0.35
-0.60	0.02	27.69	0.00	0.00	0.00	0.00	0.30
-0.50	0.02	27.69	0.00	0.00	0.00	0.00	0.28
-0.40	0.02	27.69	0.00	0.00	0.00	0.00	0.24
-0.30	0.01	27.69	0.00	0.00	0.00	0.00	0.21
-0.20	0.01	27.69	0.00	0.00	0.00	0.00	0.19
-0.10	0.01	27.68	0.00	0.00	0.00	0.00	0.18
0.00	0.01	27.68	0.00	0.00	0.00	0.00	0.17
0.10	0.01	27.68	0.00	0.00	0.00	0.00	0.16
0.20	0.01	27.68	0.00	0.00	0.00	0.00	0.17
0.30	0.01	27.68	0.00	0.00	0.00	0.00	0.17
0.40	0.01	27.67	0.00	0.00	0.00	0.00	0.17
0.50	0.01	27.67	0.00	0.00	0.00	0.00	0.19
0.60	0.01	27.67	0.00	0.00	0.00	0.00	0.22
0.70	0.02	27.66	0.00	0.00	0.00	0.00	0.23
0.80	0.02	27.66	0.00	0.00	0.00	0.00	0.25
0.90	0.02	27.66	0.00	0.00	0.00	0.00	0.28
1.00	0.02	27.66	0.00	0.00	0.00	0.00	0.31
1.10	0.03	27.65	0.00	0.00	0.00	0.00	0.36
1.20	0.03	27.65	0.00	0.00	0.00	0.00	0.40
1.30	0.03	27.65	0.00	0.00	0.00	0.00	0.43
1.40	0.04	27.65	0.00	0.00	0.00	0.00	0.47
1.50	0.04	27.65	0.00	0.00	0.00	0.00	0.50
1.60	0.04	27.65	0.00	0.00	0.00	0.00	0.55
1.70	0.05	27.65	0.00	0.00	0.00	0.00	0.60
1.80	0.05	27.64	0.00	0.00	0.00	0.00	0.64
1.90	0.06	27.64	0.00	0.00	0.00	0.00	0.69
2.00	0.06	27.64	0.00	0.00	0.00	0.00	0.73

Table 110: Call option prices for June Nino 3.4 SST conditioned on IRI ensemble forecasts released in September

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.10	27.65	0.00	0.00	0.00	0.00	1.00
-1.90	0.10	27.65	0.00	0.00	0.00	0.00	0.98
-1.80	0.09	27.65	0.00	0.00	0.00	0.00	0.92
-1.70	0.08	27.65	0.00	0.00	0.00	0.00	0.86
-1.60	0.08	27.66	0.00	0.00	0.00	0.00	0.83
-1.50	0.07	27.66	0.00	0.00	0.00	0.00	0.76
-1.40	0.06	27.66	0.00	0.00	0.00	0.00	0.71
-1.30	0.06	27.66	0.00	0.00	0.00	0.00	0.65
-1.20	0.05	27.66	0.00	0.00	0.00	0.00	0.60
-1.10	0.04	27.66	0.00	0.00	0.00	0.00	0.55
-1.00	0.04	27.66	0.00	0.00	0.00	0.00	0.51
-0.90	0.04	27.67	0.00	0.00	0.00	0.00	0.46
-0.80	0.03	27.67	0.00	0.00	0.00	0.00	0.41
-0.70	0.03	27.67	0.00	0.00	0.00	0.00	0.37
-0.60	0.02	27.67	0.00	0.00	0.00	0.00	0.32
-0.50	0.02	27.67	0.00	0.00	0.00	0.00	0.28
-0.40	0.02	27.67	0.00	0.00	0.00	0.00	0.25
-0.30	0.01	27.67	0.00	0.00	0.00	0.00	0.21
-0.20	0.01	27.67	0.00	0.00	0.00	0.00	0.19
-0.10	0.01	27.67	0.00	0.00	0.00	0.00	0.17
0.00	0.01	27.68	0.00	0.00	0.00	0.00	0.17
0.10	0.01	27.68	0.00	0.00	0.00	0.00	0.16
0.20	0.01	27.68	0.00	0.00	0.00	0.00	0.16
0.30	0.01	27.68	0.00	0.00	0.00	0.00	0.18
0.40	0.01	27.68	0.00	0.00	0.00	0.00	0.19
0.50	0.01	27.68	0.00	0.00	0.00	0.00	0.20
0.60	0.02	27.68	0.00	0.00	0.00	0.00	0.24
0.70	0.02	27.69	0.00	0.00	0.00	0.00	0.26
0.80	0.02	27.68	0.00	0.00	0.00	0.00	0.28
0.90	0.02	27.69	0.00	0.00	0.00	0.00	0.32
1.00	0.03	27.68	0.00	0.00	0.00	0.00	0.38
1.10	0.03	27.69	0.00	0.00	0.00	0.00	0.41
1.20	0.04	27.69	0.00	0.00	0.00	0.00	0.46
1.30	0.04	27.69	0.00	0.00	0.00	0.00	0.52
1.40	0.05	27.69	0.00	0.00	0.00	0.00	0.56
1.50	0.05	27.70	0.00	0.00	0.00	0.00	0.61
1.60	0.06	27.70	0.00	0.00	0.00	0.00	0.67
1.70	0.07	27.69	0.00	0.00	0.00	0.00	0.73
1.80	0.07	27.70	0.00	0.00	0.00	0.00	0.77
1.90	0.08	27.70	0.00	0.00	0.00	0.00	0.84
2.00	0.09	27.70	0.00	0.00	0.00	0.00	0.90

Table 111: Call option prices for June Nino 3.4 SST conditioned on IRI ensemble forecasts released in August

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.12	27.76	0.00	0.00	0.00	0.04	1.00
-1.90	0.11	27.76	0.00	0.00	0.00	0.02	1.00
-1.80	0.10	27.76	0.00	0.00	0.00	0.00	1.00
-1.70	0.10	27.75	0.00	0.00	0.00	0.00	0.96
-1.60	0.09	27.74	0.00	0.00	0.00	0.00	0.89
-1.50	0.08	27.74	0.00	0.00	0.00	0.00	0.82
-1.40	0.07	27.74	0.00	0.00	0.00	0.00	0.78
-1.30	0.07	27.73	0.00	0.00	0.00	0.00	0.71
-1.20	0.06	27.73	0.00	0.00	0.00	0.00	0.65
-1.10	0.05	27.73	0.00	0.00	0.00	0.00	0.60
-1.00	0.05	27.72	0.00	0.00	0.00	0.00	0.55
-0.90	0.04	27.72	0.00	0.00	0.00	0.00	0.51
-0.80	0.03	27.71	0.00	0.00	0.00	0.00	0.43
-0.70	0.03	27.71	0.00	0.00	0.00	0.00	0.41
-0.60	0.03	27.70	0.00	0.00	0.00	0.00	0.35
-0.50	0.02	27.71	0.00	0.00	0.00	0.00	0.31
-0.40	0.02	27.70	0.00	0.00	0.00	0.00	0.26
-0.30	0.02	27.70	0.00	0.00	0.00	0.00	0.24
-0.20	0.01	27.69	0.00	0.00	0.00	0.00	0.21
-0.10	0.01	27.69	0.00	0.00	0.00	0.00	0.18
0.00	0.01	27.69	0.00	0.00	0.00	0.00	0.17
0.10	0.01	27.68	0.00	0.00	0.00	0.00	0.17
0.20	0.01	27.68	0.00	0.00	0.00	0.00	0.16
0.30	0.01	27.67	0.00	0.00	0.00	0.00	0.16
0.40	0.01	27.67	0.00	0.00	0.00	0.00	0.17
0.50	0.01	27.66	0.00	0.00	0.00	0.00	0.19
0.60	0.01	27.66	0.00	0.00	0.00	0.00	0.19
0.70	0.02	27.66	0.00	0.00	0.00	0.00	0.22
0.80	0.02	27.65	0.00	0.00	0.00	0.00	0.25
0.90	0.02	27.65	0.00	0.00	0.00	0.00	0.28
1.00	0.02	27.65	0.00	0.00	0.00	0.00	0.33
1.10	0.03	27.64	0.00	0.00	0.00	0.00	0.37
1.20	0.03	27.64	0.00	0.00	0.00	0.00	0.41
1.30	0.03	27.63	0.00	0.00	0.00	0.00	0.45
1.40	0.04	27.63	0.00	0.00	0.00	0.00	0.50
1.50	0.04	27.62	0.00	0.00	0.00	0.00	0.54
1.60	0.05	27.62	0.00	0.00	0.00	0.00	0.61
1.70	0.05	27.62	0.00	0.00	0.00	0.00	0.65
1.80	0.06	27.61	0.00	0.00	0.00	0.00	0.70
1.90	0.06	27.61	0.00	0.00	0.00	0.00	0.75
2.00	0.07	27.60	0.00	0.00	0.00	0.00	0.80

Table 112: Put option prices for June Nino 3.4 SST conditioned on IRI ensemble forecasts released in April

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.73	25.98	0.00	0.51	0.92	1.00	1.00
-1.90	0.70	26.07	0.00	0.46	0.85	1.00	1.00
-1.80	0.67	26.15	0.00	0.41	0.78	1.00	1.00
-1.70	0.63	26.25	0.00	0.34	0.70	1.00	1.00
-1.60	0.59	26.33	0.00	0.29	0.63	0.97	1.00
-1.50	0.54	26.42	0.00	0.23	0.55	0.88	1.00
-1.40	0.49	26.51	0.00	0.17	0.48	0.80	1.00
-1.30	0.43	26.60	0.00	0.11	0.41	0.70	1.00
-1.20	0.38	26.69	0.00	0.05	0.33	0.62	1.00
-1.10	0.32	26.78	0.00	0.00	0.26	0.53	1.00
-1.00	0.26	26.87	0.00	0.00	0.19	0.44	1.00
-0.90	0.21	26.95	0.00	0.00	0.11	0.36	0.90
-0.80	0.16	27.04	0.00	0.00	0.04	0.27	0.79
-0.70	0.12	27.13	0.00	0.00	0.00	0.19	0.67
-0.60	0.08	27.22	0.00	0.00	0.00	0.10	0.57
-0.50	0.06	27.31	0.00	0.00	0.00	0.02	0.47
-0.40	0.04	27.40	0.00	0.00	0.00	0.00	0.37
-0.30	0.02	27.49	0.00	0.00	0.00	0.00	0.28
-0.20	0.01	27.58	0.00	0.00	0.00	0.00	0.19
-0.10	0.01	27.66	0.00	0.00	0.00	0.00	0.11
0.00	0.01	27.75	0.00	0.00	0.00	0.00	0.04
0.10	0.00	27.84	0.00	0.00	0.00	0.00	0.00
0.20	0.00	27.92	0.00	0.00	0.00	0.00	0.00
0.30	0.00	28.01	0.00	0.00	0.00	0.00	0.00
0.40	0.00	28.10	0.00	0.00	0.00	0.00	0.00
0.50	0.00	28.19	0.00	0.00	0.00	0.00	0.00
0.60	0.00	28.28	0.00	0.00	0.00	0.00	0.00
0.70	0.00	28.37	0.00	0.00	0.00	0.00	0.00
0.80	0.00	28.46	0.00	0.00	0.00	0.00	0.00
0.90	0.00	28.55	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.63	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.72	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.81	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.90	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.99	0.00	0.00	0.00	0.00	0.00
1.50	0.00	29.07	0.00	0.00	0.00	0.00	0.00
1.60	0.00	29.16	0.00	0.00	0.00	0.00	0.00
1.70	0.00	29.25	0.00	0.00	0.00	0.00	0.00
1.80	0.00	29.34	0.00	0.00	0.00	0.00	0.00
1.90	0.00	29.43	0.00	0.00	0.00	0.00	0.00
2.00	0.00	29.52	0.00	0.00	0.00	0.00	0.00

Table 113: Put option prices for June Nino 3.4 SST conditioned on IRI ensemble forecasts released in March

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.57	26.36	0.00	0.20	0.61	1.00	1.00
-1.90	0.53	26.43	0.00	0.16	0.56	0.95	1.00
-1.80	0.50	26.50	0.00	0.12	0.49	0.87	1.00
-1.70	0.46	26.56	0.00	0.07	0.44	0.80	1.00
-1.60	0.42	26.63	0.00	0.03	0.38	0.73	1.00
-1.50	0.38	26.70	0.00	0.00	0.32	0.66	1.00
-1.40	0.34	26.77	0.00	0.00	0.27	0.59	1.00
-1.30	0.30	26.84	0.00	0.00	0.21	0.51	1.00
-1.20	0.26	26.91	0.00	0.00	0.15	0.44	1.00
-1.10	0.22	26.98	0.00	0.00	0.09	0.37	1.00
-1.00	0.18	27.05	0.00	0.00	0.04	0.31	0.89
-0.90	0.15	27.11	0.00	0.00	0.00	0.23	0.79
-0.80	0.11	27.19	0.00	0.00	0.00	0.16	0.71
-0.70	0.09	27.26	0.00	0.00	0.00	0.10	0.62
-0.60	0.06	27.32	0.00	0.00	0.00	0.03	0.53
-0.50	0.05	27.39	0.00	0.00	0.00	0.00	0.45
-0.40	0.03	27.46	0.00	0.00	0.00	0.00	0.37
-0.30	0.02	27.53	0.00	0.00	0.00	0.00	0.29
-0.20	0.02	27.60	0.00	0.00	0.00	0.00	0.22
-0.10	0.01	27.67	0.00	0.00	0.00	0.00	0.15
0.00	0.01	27.74	0.00	0.00	0.00	0.00	0.09
0.10	0.01	27.81	0.00	0.00	0.00	0.00	0.05
0.20	0.00	27.88	0.00	0.00	0.00	0.00	0.00
0.30	0.00	27.94	0.00	0.00	0.00	0.00	0.00
0.40	0.00	28.01	0.00	0.00	0.00	0.00	0.00
0.50	0.00	28.09	0.00	0.00	0.00	0.00	0.00
0.60	0.00	28.16	0.00	0.00	0.00	0.00	0.00
0.70	0.00	28.22	0.00	0.00	0.00	0.00	0.00
0.80	0.00	28.29	0.00	0.00	0.00	0.00	0.00
0.90	0.00	28.36	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.43	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.50	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.57	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.64	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.71	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.78	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.85	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.92	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.99	0.00	0.00	0.00	0.00	0.00
1.90	0.00	29.05	0.00	0.00	0.00	0.00	0.00
2.00	0.00	29.12	0.00	0.00	0.00	0.00	0.00

Table 114: Put option prices for June Nino 3.4 SST conditioned on IRI ensemble forecasts released in February

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.27	26.97	0.00	0.00	0.10	0.49	1.00
-1.90	0.25	27.01	0.00	0.00	0.07	0.45	1.00
-1.80	0.24	27.04	0.00	0.00	0.04	0.41	1.00
-1.70	0.22	27.08	0.00	0.00	0.02	0.37	1.00
-1.60	0.20	27.11	0.00	0.00	0.00	0.33	1.00
-1.50	0.18	27.14	0.00	0.00	0.00	0.29	1.00
-1.40	0.16	27.18	0.00	0.00	0.00	0.24	0.96
-1.30	0.14	27.21	0.00	0.00	0.00	0.20	0.89
-1.20	0.12	27.24	0.00	0.00	0.00	0.17	0.81
-1.10	0.11	27.27	0.00	0.00	0.00	0.12	0.77
-1.00	0.09	27.31	0.00	0.00	0.00	0.08	0.68
-0.90	0.08	27.34	0.00	0.00	0.00	0.05	0.63
-0.80	0.06	27.38	0.00	0.00	0.00	0.01	0.57
-0.70	0.05	27.41	0.00	0.00	0.00	0.00	0.51
-0.60	0.04	27.44	0.00	0.00	0.00	0.00	0.45
-0.50	0.04	27.47	0.00	0.00	0.00	0.00	0.40
-0.40	0.03	27.51	0.00	0.00	0.00	0.00	0.36
-0.30	0.02	27.54	0.00	0.00	0.00	0.00	0.31
-0.20	0.02	27.58	0.00	0.00	0.00	0.00	0.25
-0.10	0.02	27.61	0.00	0.00	0.00	0.00	0.22
0.00	0.01	27.64	0.00	0.00	0.00	0.00	0.20
0.10	0.01	27.68	0.00	0.00	0.00	0.00	0.16
0.20	0.01	27.71	0.00	0.00	0.00	0.00	0.15
0.30	0.01	27.74	0.00	0.00	0.00	0.00	0.12
0.40	0.01	27.78	0.00	0.00	0.00	0.00	0.12
0.50	0.01	27.81	0.00	0.00	0.00	0.00	0.09
0.60	0.01	27.84	0.00	0.00	0.00	0.00	0.10
0.70	0.01	27.88	0.00	0.00	0.00	0.00	0.09
0.80	0.01	27.91	0.00	0.00	0.00	0.00	0.09
0.90	0.01	27.95	0.00	0.00	0.00	0.00	0.10
1.00	0.01	27.98	0.00	0.00	0.00	0.00	0.10
1.10	0.01	28.01	0.00	0.00	0.00	0.00	0.11
1.20	0.01	28.04	0.00	0.00	0.00	0.00	0.13
1.30	0.01	28.08	0.00	0.00	0.00	0.00	0.14
1.40	0.01	28.11	0.00	0.00	0.00	0.00	0.15
1.50	0.01	28.15	0.00	0.00	0.00	0.00	0.17
1.60	0.01	28.18	0.00	0.00	0.00	0.00	0.18
1.70	0.01	28.21	0.00	0.00	0.00	0.00	0.19
1.80	0.02	28.25	0.00	0.00	0.00	0.00	0.21
1.90	0.02	28.28	0.00	0.00	0.00	0.00	0.23
2.00	0.02	28.31	0.00	0.00	0.00	0.00	0.25

Table 115: Put option prices for June Nino 3.4 SST conditioned on IRI ensemble forecasts released in January

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.14	27.33	0.00	0.00	0.00	0.17	1.00
-1.90	0.13	27.35	0.00	0.00	0.00	0.14	0.95
-1.80	0.12	27.37	0.00	0.00	0.00	0.11	0.91
-1.70	0.10	27.39	0.00	0.00	0.00	0.09	0.84
-1.60	0.10	27.40	0.00	0.00	0.00	0.06	0.78
-1.50	0.09	27.42	0.00	0.00	0.00	0.03	0.74
-1.40	0.08	27.44	0.00	0.00	0.00	0.01	0.69
-1.30	0.07	27.45	0.00	0.00	0.00	0.00	0.64
-1.20	0.06	27.47	0.00	0.00	0.00	0.00	0.58
-1.10	0.05	27.48	0.00	0.00	0.00	0.00	0.53
-1.00	0.05	27.50	0.00	0.00	0.00	0.00	0.48
-0.90	0.04	27.52	0.00	0.00	0.00	0.00	0.45
-0.80	0.03	27.54	0.00	0.00	0.00	0.00	0.40
-0.70	0.03	27.55	0.00	0.00	0.00	0.00	0.37
-0.60	0.03	27.57	0.00	0.00	0.00	0.00	0.33
-0.50	0.02	27.59	0.00	0.00	0.00	0.00	0.29
-0.40	0.02	27.60	0.00	0.00	0.00	0.00	0.27
-0.30	0.02	27.62	0.00	0.00	0.00	0.00	0.24
-0.20	0.01	27.64	0.00	0.00	0.00	0.00	0.21
-0.10	0.01	27.65	0.00	0.00	0.00	0.00	0.20
0.00	0.01	27.67	0.00	0.00	0.00	0.00	0.16
0.10	0.01	27.68	0.00	0.00	0.00	0.00	0.16
0.20	0.01	27.70	0.00	0.00	0.00	0.00	0.14
0.30	0.01	27.72	0.00	0.00	0.00	0.00	0.14
0.40	0.01	27.74	0.00	0.00	0.00	0.00	0.13
0.50	0.01	27.75	0.00	0.00	0.00	0.00	0.13
0.60	0.01	27.77	0.00	0.00	0.00	0.00	0.14
0.70	0.01	27.78	0.00	0.00	0.00	0.00	0.14
0.80	0.01	27.80	0.00	0.00	0.00	0.00	0.16
0.90	0.01	27.82	0.00	0.00	0.00	0.00	0.17
1.00	0.01	27.84	0.00	0.00	0.00	0.00	0.18
1.10	0.01	27.85	0.00	0.00	0.00	0.00	0.21
1.20	0.01	27.87	0.00	0.00	0.00	0.00	0.21
1.30	0.02	27.88	0.00	0.00	0.00	0.00	0.24
1.40	0.02	27.90	0.00	0.00	0.00	0.00	0.27
1.50	0.02	27.92	0.00	0.00	0.00	0.00	0.27
1.60	0.02	27.93	0.00	0.00	0.00	0.00	0.31
1.70	0.02	27.95	0.00	0.00	0.00	0.00	0.33
1.80	0.02	27.96	0.00	0.00	0.00	0.00	0.35
1.90	0.02	27.98	0.00	0.00	0.00	0.00	0.37
2.00	0.03	28.00	0.00	0.00	0.00	0.00	0.39

Table 116: Put option prices for June Nino 3.4 SST conditioned on IRI ensemble forecasts released in December

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.10	27.50	0.00	0.00	0.00	0.04	0.89
-1.90	0.09	27.51	0.00	0.00	0.00	0.02	0.83
-1.80	0.09	27.52	0.00	0.00	0.00	0.00	0.80
-1.70	0.08	27.52	0.00	0.00	0.00	0.00	0.75
-1.60	0.07	27.53	0.00	0.00	0.00	0.00	0.70
-1.50	0.06	27.54	0.00	0.00	0.00	0.00	0.65
-1.40	0.06	27.55	0.00	0.00	0.00	0.00	0.62
-1.30	0.05	27.56	0.00	0.00	0.00	0.00	0.57
-1.20	0.05	27.57	0.00	0.00	0.00	0.00	0.52
-1.10	0.04	27.58	0.00	0.00	0.00	0.00	0.48
-1.00	0.04	27.58	0.00	0.00	0.00	0.00	0.45
-0.90	0.03	27.59	0.00	0.00	0.00	0.00	0.41
-0.80	0.03	27.60	0.00	0.00	0.00	0.00	0.37
-0.70	0.02	27.61	0.00	0.00	0.00	0.00	0.33
-0.60	0.02	27.62	0.00	0.00	0.00	0.00	0.31
-0.50	0.02	27.63	0.00	0.00	0.00	0.00	0.26
-0.40	0.02	27.64	0.00	0.00	0.00	0.00	0.25
-0.30	0.02	27.65	0.00	0.00	0.00	0.00	0.22
-0.20	0.01	27.66	0.00	0.00	0.00	0.00	0.21
-0.10	0.01	27.66	0.00	0.00	0.00	0.00	0.19
0.00	0.01	27.67	0.00	0.00	0.00	0.00	0.18
0.10	0.01	27.68	0.00	0.00	0.00	0.00	0.17
0.20	0.01	27.69	0.00	0.00	0.00	0.00	0.17
0.30	0.01	27.69	0.00	0.00	0.00	0.00	0.17
0.40	0.01	27.71	0.00	0.00	0.00	0.00	0.17
0.50	0.01	27.71	0.00	0.00	0.00	0.00	0.19
0.60	0.01	27.72	0.00	0.00	0.00	0.00	0.18
0.70	0.01	27.73	0.00	0.00	0.00	0.00	0.19
0.80	0.01	27.74	0.00	0.00	0.00	0.00	0.21
0.90	0.01	27.75	0.00	0.00	0.00	0.00	0.22
1.00	0.02	27.75	0.00	0.00	0.00	0.00	0.25
1.10	0.02	27.77	0.00	0.00	0.00	0.00	0.28
1.20	0.02	27.77	0.00	0.00	0.00	0.00	0.30
1.30	0.02	27.78	0.00	0.00	0.00	0.00	0.32
1.40	0.02	27.79	0.00	0.00	0.00	0.00	0.34
1.50	0.03	27.80	0.00	0.00	0.00	0.00	0.38
1.60	0.03	27.81	0.00	0.00	0.00	0.00	0.40
1.70	0.03	27.82	0.00	0.00	0.00	0.00	0.42
1.80	0.03	27.83	0.00	0.00	0.00	0.00	0.48
1.90	0.04	27.83	0.00	0.00	0.00	0.00	0.49
2.00	0.04	27.84	0.00	0.00	0.00	0.00	0.53

Table 117: Put option prices for June Nino 3.4 SST conditioned on IRI ensemble forecasts released in November

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.06	27.78	0.00	0.00	0.00	0.00	0.73
-1.90	0.06	27.77	0.00	0.00	0.00	0.00	0.71
-1.80	0.06	27.77	0.00	0.00	0.00	0.00	0.65
-1.70	0.05	27.76	0.00	0.00	0.00	0.00	0.62
-1.60	0.05	27.76	0.00	0.00	0.00	0.00	0.58
-1.50	0.04	27.76	0.00	0.00	0.00	0.00	0.54
-1.40	0.04	27.75	0.00	0.00	0.00	0.00	0.50
-1.30	0.04	27.75	0.00	0.00	0.00	0.00	0.47
-1.20	0.03	27.74	0.00	0.00	0.00	0.00	0.44
-1.10	0.03	27.74	0.00	0.00	0.00	0.00	0.40
-1.00	0.03	27.73	0.00	0.00	0.00	0.00	0.37
-0.90	0.02	27.72	0.00	0.00	0.00	0.00	0.34
-0.80	0.02	27.72	0.00	0.00	0.00	0.00	0.30
-0.70	0.02	27.72	0.00	0.00	0.00	0.00	0.29
-0.60	0.02	27.71	0.00	0.00	0.00	0.00	0.25
-0.50	0.02	27.71	0.00	0.00	0.00	0.00	0.22
-0.40	0.01	27.70	0.00	0.00	0.00	0.00	0.21
-0.30	0.01	27.70	0.00	0.00	0.00	0.00	0.20
-0.20	0.01	27.69	0.00	0.00	0.00	0.00	0.19
-0.10	0.01	27.69	0.00	0.00	0.00	0.00	0.17
0.00	0.01	27.68	0.00	0.00	0.00	0.00	0.18
0.10	0.01	27.68	0.00	0.00	0.00	0.00	0.17
0.20	0.01	27.67	0.00	0.00	0.00	0.00	0.18
0.30	0.01	27.66	0.00	0.00	0.00	0.00	0.20
0.40	0.01	27.66	0.00	0.00	0.00	0.00	0.21
0.50	0.02	27.66	0.00	0.00	0.00	0.00	0.23
0.60	0.02	27.65	0.00	0.00	0.00	0.00	0.25
0.70	0.02	27.65	0.00	0.00	0.00	0.00	0.26
0.80	0.02	27.65	0.00	0.00	0.00	0.00	0.29
0.90	0.02	27.64	0.00	0.00	0.00	0.00	0.33
1.00	0.03	27.63	0.00	0.00	0.00	0.00	0.37
1.10	0.03	27.63	0.00	0.00	0.00	0.00	0.40
1.20	0.04	27.63	0.00	0.00	0.00	0.00	0.44
1.30	0.04	27.62	0.00	0.00	0.00	0.00	0.47
1.40	0.04	27.61	0.00	0.00	0.00	0.00	0.51
1.50	0.05	27.61	0.00	0.00	0.00	0.00	0.57
1.60	0.06	27.60	0.00	0.00	0.00	0.00	0.61
1.70	0.06	27.60	0.00	0.00	0.00	0.00	0.68
1.80	0.07	27.59	0.00	0.00	0.00	0.00	0.70
1.90	0.07	27.59	0.00	0.00	0.00	0.00	0.75
2.00	0.08	27.59	0.00	0.00	0.00	0.00	0.81

Table 118: Put option prices for June Nino 3.4 SST conditioned on IRI ensemble forecasts released in October

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.08	27.73	0.00	0.00	0.00	0.00	0.87
-1.90	0.07	27.72	0.00	0.00	0.00	0.00	0.81
-1.80	0.07	27.72	0.00	0.00	0.00	0.00	0.76
-1.70	0.06	27.71	0.00	0.00	0.00	0.00	0.71
-1.60	0.06	27.71	0.00	0.00	0.00	0.00	0.68
-1.50	0.05	27.71	0.00	0.00	0.00	0.00	0.62
-1.40	0.05	27.71	0.00	0.00	0.00	0.00	0.58
-1.30	0.04	27.71	0.00	0.00	0.00	0.00	0.55
-1.20	0.04	27.71	0.00	0.00	0.00	0.00	0.50
-1.10	0.04	27.71	0.00	0.00	0.00	0.00	0.45
-1.00	0.03	27.70	0.00	0.00	0.00	0.00	0.41
-0.90	0.03	27.70	0.00	0.00	0.00	0.00	0.38
-0.80	0.03	27.70	0.00	0.00	0.00	0.00	0.35
-0.70	0.02	27.69	0.00	0.00	0.00	0.00	0.32
-0.60	0.02	27.69	0.00	0.00	0.00	0.00	0.28
-0.50	0.02	27.69	0.00	0.00	0.00	0.00	0.25
-0.40	0.02	27.69	0.00	0.00	0.00	0.00	0.24
-0.30	0.01	27.69	0.00	0.00	0.00	0.00	0.21
-0.20	0.01	27.69	0.00	0.00	0.00	0.00	0.19
-0.10	0.01	27.68	0.00	0.00	0.00	0.00	0.19
0.00	0.01	27.68	0.00	0.00	0.00	0.00	0.18
0.10	0.01	27.68	0.00	0.00	0.00	0.00	0.17
0.20	0.01	27.68	0.00	0.00	0.00	0.00	0.18
0.30	0.01	27.68	0.00	0.00	0.00	0.00	0.20
0.40	0.01	27.67	0.00	0.00	0.00	0.00	0.20
0.50	0.01	27.67	0.00	0.00	0.00	0.00	0.22
0.60	0.02	27.67	0.00	0.00	0.00	0.00	0.25
0.70	0.02	27.66	0.00	0.00	0.00	0.00	0.27
0.80	0.02	27.66	0.00	0.00	0.00	0.00	0.29
0.90	0.03	27.66	0.00	0.00	0.00	0.00	0.35
1.00	0.03	27.66	0.00	0.00	0.00	0.00	0.38
1.10	0.03	27.65	0.00	0.00	0.00	0.00	0.41
1.20	0.04	27.65	0.00	0.00	0.00	0.00	0.45
1.30	0.04	27.65	0.00	0.00	0.00	0.00	0.50
1.40	0.04	27.65	0.00	0.00	0.00	0.00	0.53
1.50	0.05	27.65	0.00	0.00	0.00	0.00	0.58
1.60	0.06	27.65	0.00	0.00	0.00	0.00	0.63
1.70	0.06	27.65	0.00	0.00	0.00	0.00	0.67
1.80	0.07	27.64	0.00	0.00	0.00	0.00	0.73
1.90	0.07	27.64	0.00	0.00	0.00	0.00	0.78
2.00	0.08	27.64	0.00	0.00	0.00	0.00	0.84

Table 119: Put option prices for June Nino 3.4 SST conditioned on IRI ensemble forecasts released in September

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.12	27.65	0.00	0.00	0.00	0.03	1.00
-1.90	0.11	27.65	0.00	0.00	0.00	0.01	1.00
-1.80	0.10	27.65	0.00	0.00	0.00	0.00	0.97
-1.70	0.09	27.65	0.00	0.00	0.00	0.00	0.93
-1.60	0.09	27.66	0.00	0.00	0.00	0.00	0.87
-1.50	0.08	27.66	0.00	0.00	0.00	0.00	0.80
-1.40	0.07	27.66	0.00	0.00	0.00	0.00	0.76
-1.30	0.06	27.66	0.00	0.00	0.00	0.00	0.68
-1.20	0.06	27.66	0.00	0.00	0.00	0.00	0.64
-1.10	0.05	27.66	0.00	0.00	0.00	0.00	0.60
-1.00	0.05	27.66	0.00	0.00	0.00	0.00	0.54
-0.90	0.04	27.67	0.00	0.00	0.00	0.00	0.49
-0.80	0.03	27.67	0.00	0.00	0.00	0.00	0.43
-0.70	0.03	27.67	0.00	0.00	0.00	0.00	0.40
-0.60	0.03	27.67	0.00	0.00	0.00	0.00	0.36
-0.50	0.02	27.67	0.00	0.00	0.00	0.00	0.32
-0.40	0.02	27.67	0.00	0.00	0.00	0.00	0.27
-0.30	0.02	27.67	0.00	0.00	0.00	0.00	0.25
-0.20	0.01	27.67	0.00	0.00	0.00	0.00	0.22
-0.10	0.01	27.67	0.00	0.00	0.00	0.00	0.20
0.00	0.01	27.68	0.00	0.00	0.00	0.00	0.19
0.10	0.01	27.68	0.00	0.00	0.00	0.00	0.18
0.20	0.01	27.68	0.00	0.00	0.00	0.00	0.18
0.30	0.01	27.68	0.00	0.00	0.00	0.00	0.18
0.40	0.01	27.68	0.00	0.00	0.00	0.00	0.19
0.50	0.01	27.68	0.00	0.00	0.00	0.00	0.21
0.60	0.02	27.68	0.00	0.00	0.00	0.00	0.24
0.70	0.02	27.69	0.00	0.00	0.00	0.00	0.26
0.80	0.02	27.68	0.00	0.00	0.00	0.00	0.30
0.90	0.02	27.69	0.00	0.00	0.00	0.00	0.33
1.00	0.03	27.68	0.00	0.00	0.00	0.00	0.38
1.10	0.03	27.69	0.00	0.00	0.00	0.00	0.41
1.20	0.04	27.69	0.00	0.00	0.00	0.00	0.46
1.30	0.04	27.69	0.00	0.00	0.00	0.00	0.51
1.40	0.05	27.69	0.00	0.00	0.00	0.00	0.56
1.50	0.05	27.70	0.00	0.00	0.00	0.00	0.59
1.60	0.06	27.70	0.00	0.00	0.00	0.00	0.65
1.70	0.06	27.69	0.00	0.00	0.00	0.00	0.73
1.80	0.07	27.70	0.00	0.00	0.00	0.00	0.76
1.90	0.08	27.70	0.00	0.00	0.00	0.00	0.81
2.00	0.08	27.70	0.00	0.00	0.00	0.00	0.88

Table 120: Put option prices for June Nino 3.4 SST conditioned on IRI ensemble forecasts released in August

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.09	27.76	0.00	0.00	0.00	0.00	1.00
-1.90	0.09	27.76	0.00	0.00	0.00	0.00	0.94
-1.80	0.08	27.76	0.00	0.00	0.00	0.00	0.89
-1.70	0.08	27.75	0.00	0.00	0.00	0.00	0.83
-1.60	0.07	27.74	0.00	0.00	0.00	0.00	0.78
-1.50	0.06	27.74	0.00	0.00	0.00	0.00	0.74
-1.40	0.06	27.74	0.00	0.00	0.00	0.00	0.67
-1.30	0.05	27.73	0.00	0.00	0.00	0.00	0.63
-1.20	0.05	27.73	0.00	0.00	0.00	0.00	0.57
-1.10	0.04	27.73	0.00	0.00	0.00	0.00	0.52
-1.00	0.04	27.72	0.00	0.00	0.00	0.00	0.48
-0.90	0.03	27.72	0.00	0.00	0.00	0.00	0.44
-0.80	0.03	27.71	0.00	0.00	0.00	0.00	0.40
-0.70	0.03	27.71	0.00	0.00	0.00	0.00	0.35
-0.60	0.02	27.70	0.00	0.00	0.00	0.00	0.32
-0.50	0.02	27.71	0.00	0.00	0.00	0.00	0.27
-0.40	0.02	27.70	0.00	0.00	0.00	0.00	0.24
-0.30	0.02	27.70	0.00	0.00	0.00	0.00	0.22
-0.20	0.01	27.69	0.00	0.00	0.00	0.00	0.20
-0.10	0.01	27.69	0.00	0.00	0.00	0.00	0.18
0.00	0.01	27.69	0.00	0.00	0.00	0.00	0.17
0.10	0.01	27.68	0.00	0.00	0.00	0.00	0.17
0.20	0.01	27.68	0.00	0.00	0.00	0.00	0.18
0.30	0.01	27.67	0.00	0.00	0.00	0.00	0.18
0.40	0.01	27.67	0.00	0.00	0.00	0.00	0.21
0.50	0.01	27.66	0.00	0.00	0.00	0.00	0.21
0.60	0.02	27.66	0.00	0.00	0.00	0.00	0.25
0.70	0.02	27.66	0.00	0.00	0.00	0.00	0.27
0.80	0.02	27.65	0.00	0.00	0.00	0.00	0.32
0.90	0.03	27.65	0.00	0.00	0.00	0.00	0.36
1.00	0.03	27.65	0.00	0.00	0.00	0.00	0.42
1.10	0.04	27.64	0.00	0.00	0.00	0.00	0.45
1.20	0.04	27.64	0.00	0.00	0.00	0.00	0.49
1.30	0.05	27.63	0.00	0.00	0.00	0.00	0.56
1.40	0.05	27.63	0.00	0.00	0.00	0.00	0.58
1.50	0.06	27.62	0.00	0.00	0.00	0.00	0.66
1.60	0.07	27.62	0.00	0.00	0.00	0.00	0.72
1.70	0.07	27.62	0.00	0.00	0.00	0.00	0.76
1.80	0.08	27.61	0.00	0.00	0.00	0.00	0.84
1.90	0.09	27.61	0.00	0.00	0.00	0.00	0.90
2.00	0.10	27.60	0.00	0.00	0.00	0.00	0.94

Appendix J: July Pricing

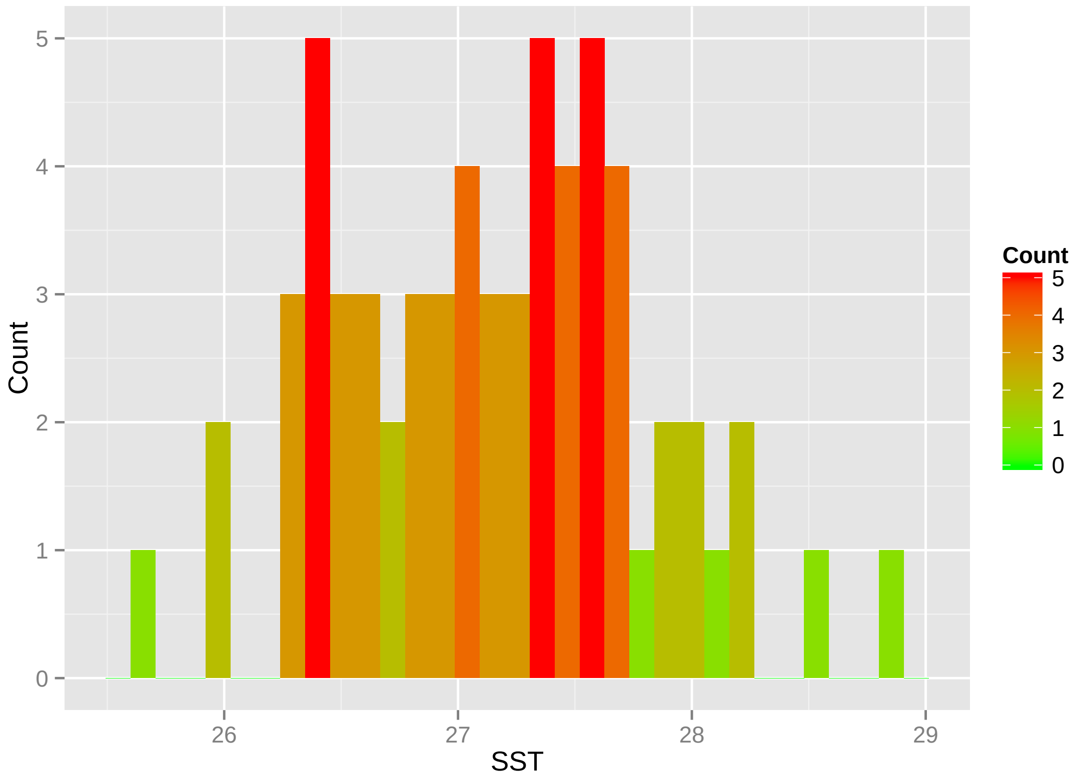


Figure 71: Histogram of July SST for Niño 3.4 ERSST.3b

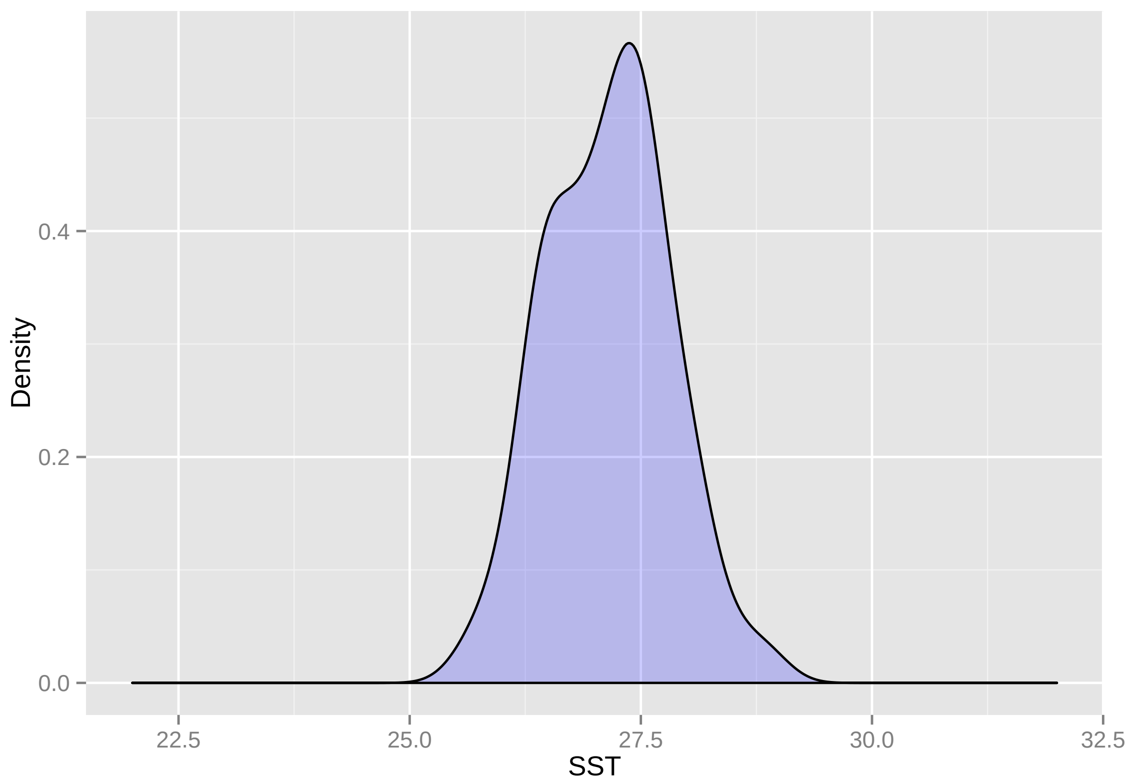


Figure 72: Kernel density estimate of July SST for Niño 3.4 ERSST.3b

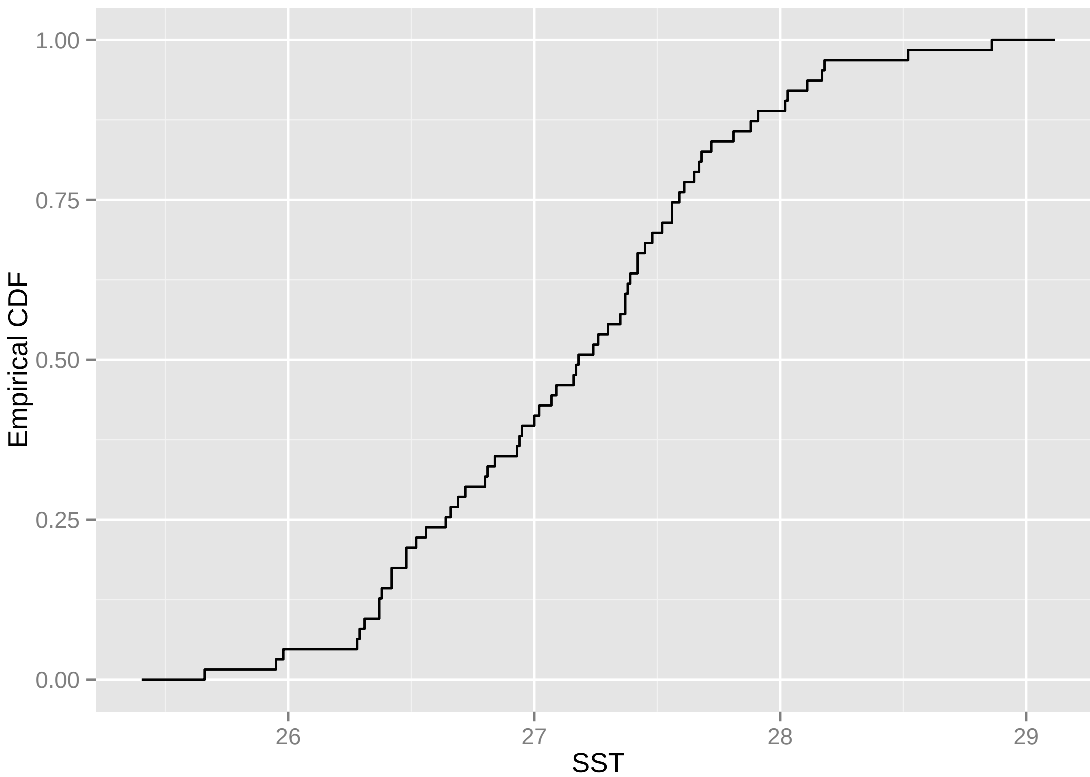


Figure 73: ECDF of July SST for Niño 3.4 ERSST.3b

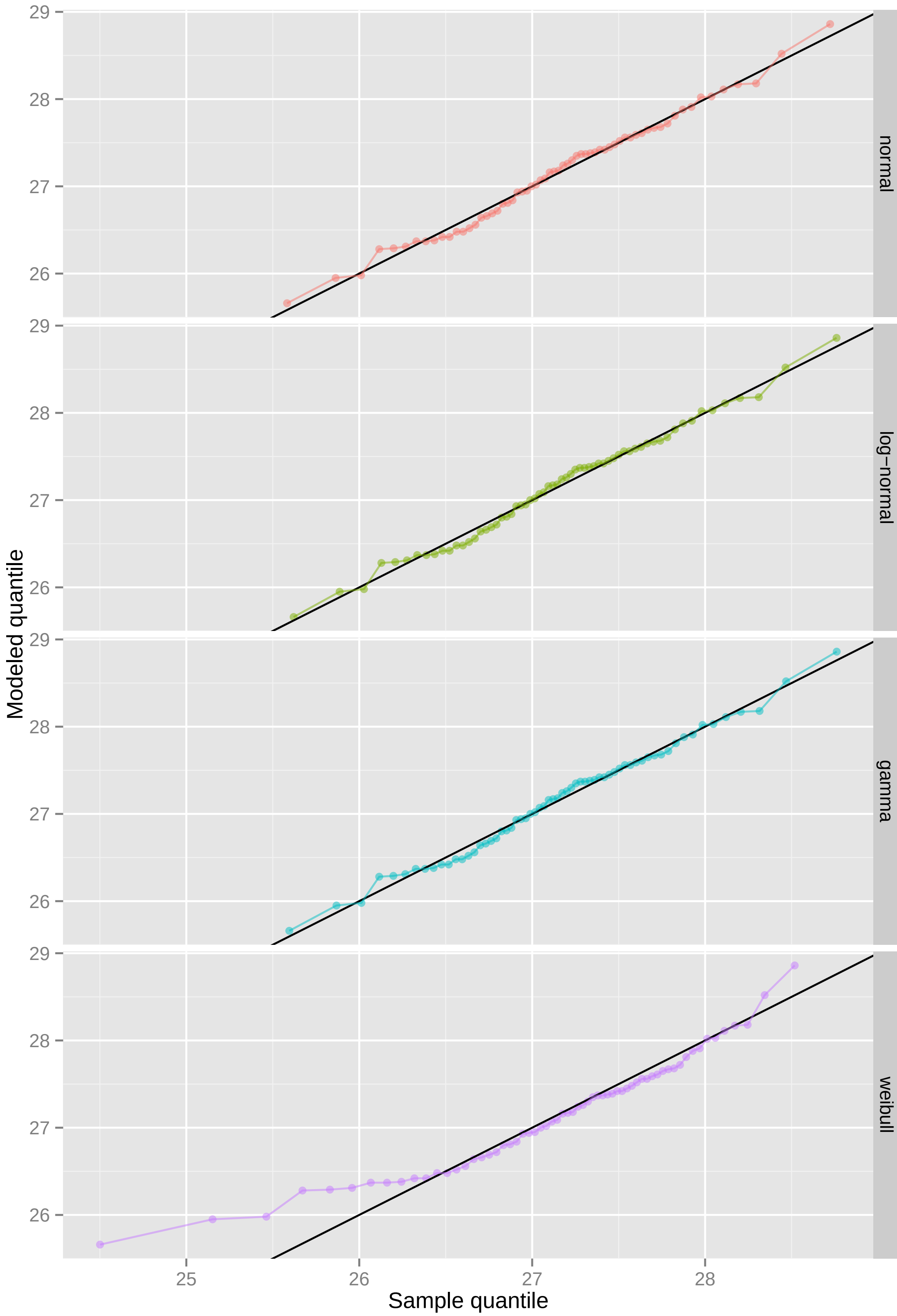


Figure 74: QQ plots of July SST for Niño 3.4 ERSST.3b compared to samples from various distributions (n=2 million)

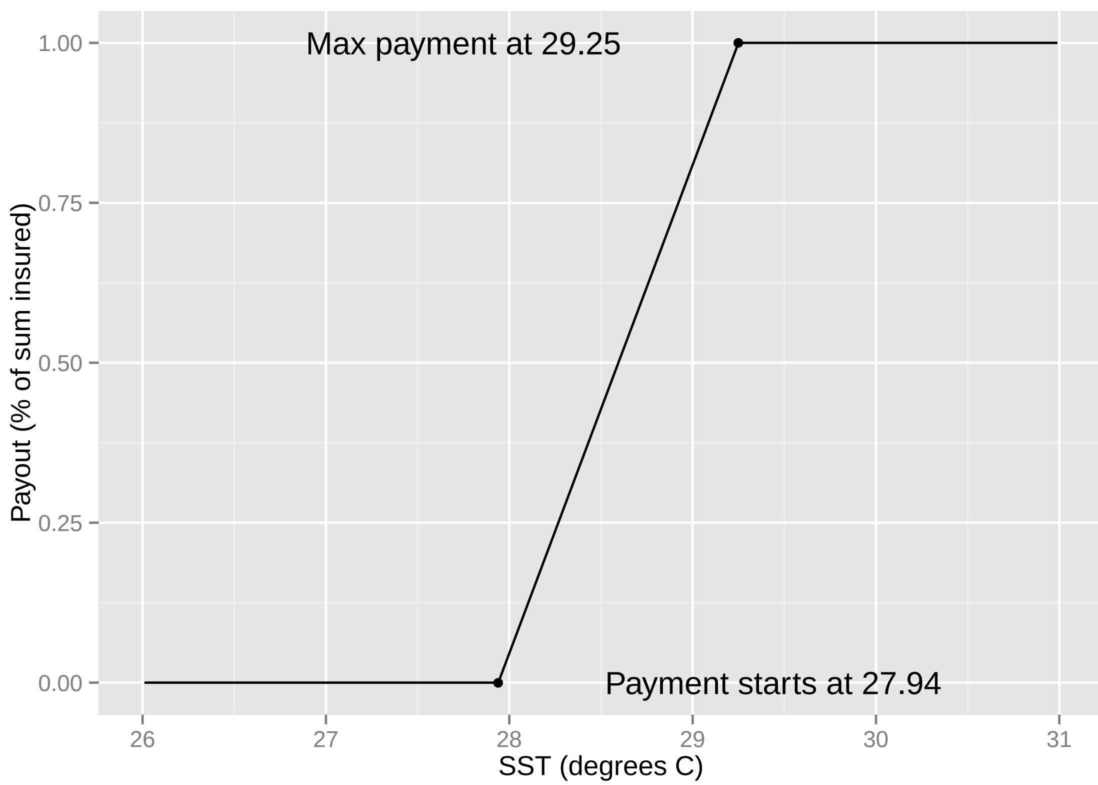


Figure 75: Payout function for call option on July SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations above the baseline

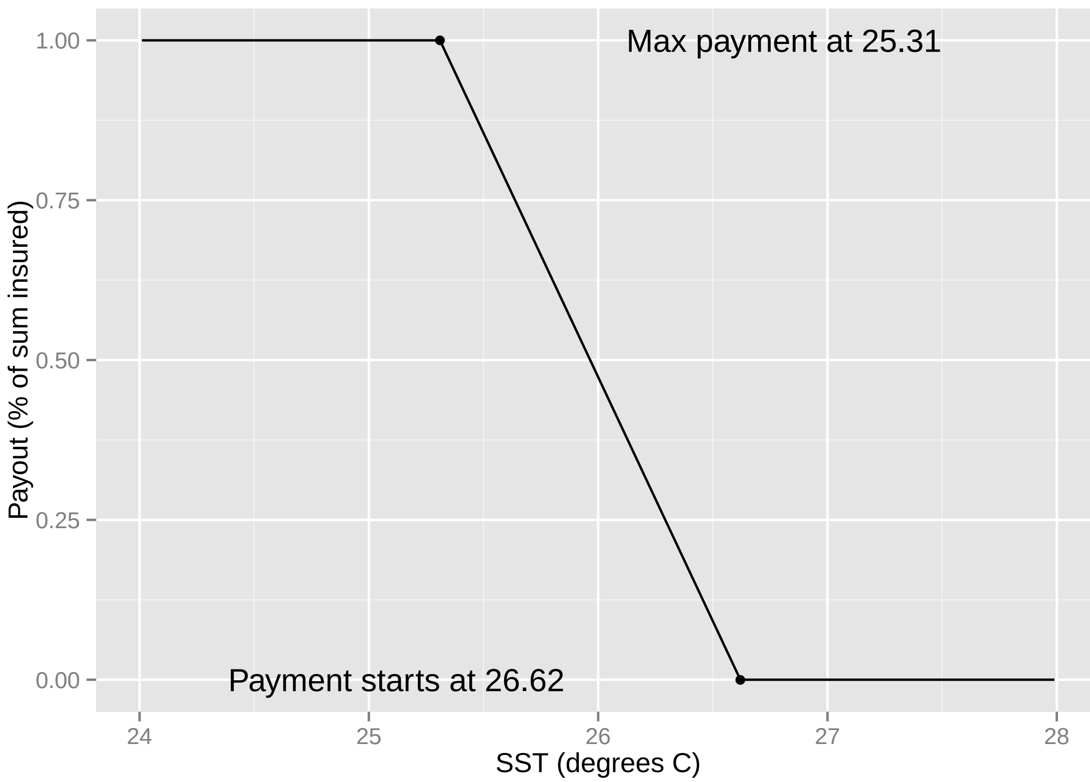


Figure 76: Payout function for put option on July SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

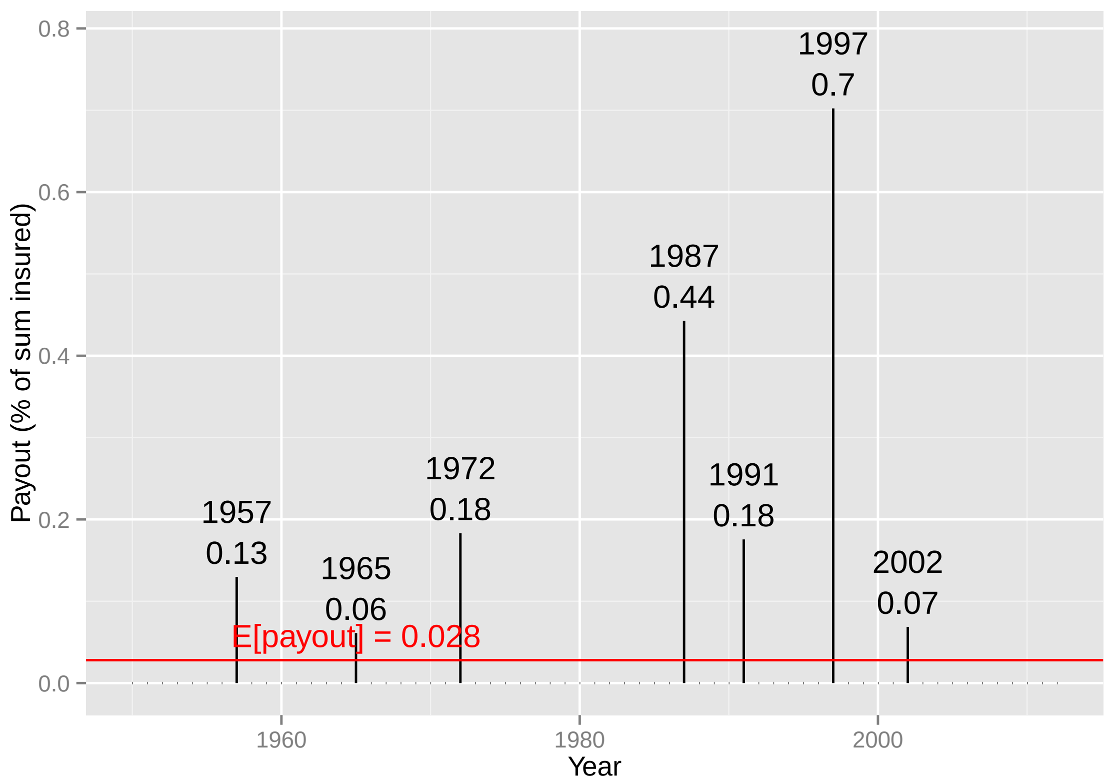


Figure 77: Historical burn on call option for July SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations above the baseline

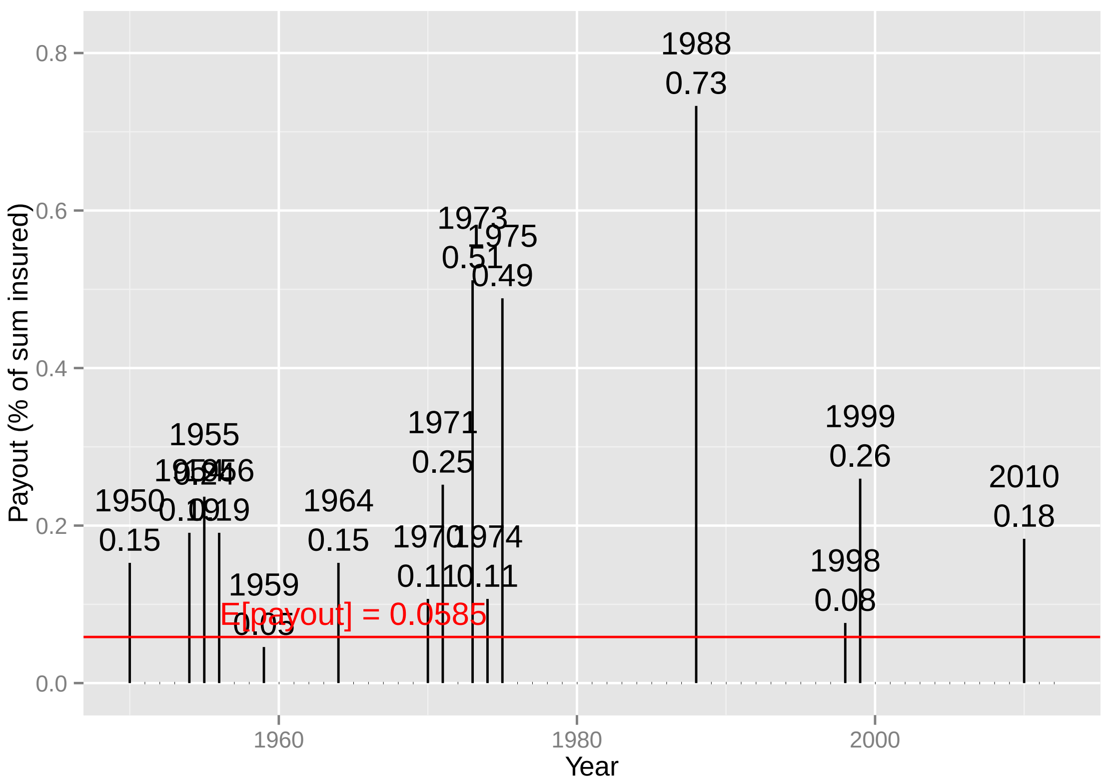


Figure 78: Historical burn on put option on July SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

Table 121: Bayesian regression linking July Niño 3.4 SST anomalies to average of relevant IRI ensemble forecasts

	mean	sd	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q	n_eff	Rhat
May forecast average covering July Niño 3.4 SST anomalies									
α	0.00	0.10	-0.20	0.00	0.00	0.10	0.30	102201	1
β	1.00	0.40	0.20	0.80	1.00	1.30	1.90	99676	1
σ_y^2	0.20	0.10	0.10	0.10	0.20	0.20	0.50	61246	1
April forecast average covering July Niño 3.4 SST anomalies									
α	0.00	0.10	-0.20	0.00	0.00	0.10	0.30	99770	1
β	1.20	0.40	0.30	0.90	1.20	1.40	2.00	97765	1
σ_y^2	0.20	0.10	0.10	0.10	0.10	0.20	0.40	58488	1
March forecast average covering July Niño 3.4 SST anomalies									
α	0.00	0.10	-0.20	0.00	0.00	0.10	0.30	101405	1
β	0.90	0.50	-0.10	0.60	0.90	1.20	1.80	95796	1
σ_y^2	0.20	0.10	0.10	0.10	0.20	0.30	0.60	58910	1
February forecast average covering July Niño 3.4 SST anomalies									
α	0.00	0.20	-0.40	-0.10	0.00	0.10	0.40	95554	1
β	0.40	0.60	-0.90	0.00	0.40	0.70	1.60	86939	1
σ_y^2	0.30	0.30	0.10	0.20	0.30	0.40	1.00	56281	1
January forecast average covering July Niño 3.4 SST anomalies									
α	0.00	0.20	-0.30	-0.10	0.00	0.10	0.30	101251	1
β	0.20	0.60	-0.90	-0.10	0.20	0.50	1.30	93996	1
σ_y^2	0.30	0.20	0.10	0.20	0.20	0.40	0.80	59364	1
December forecast average covering July Niño 3.4 SST anomalies									
α	0.00	0.20	-0.30	-0.10	0.00	0.10	0.30	95598	1
β	0.10	0.60	-1.00	-0.20	0.10	0.50	1.20	91985	1
σ_y^2	0.30	0.20	0.10	0.20	0.20	0.40	0.80	58947	1
November forecast average covering July Niño 3.4 SST anomalies									
α	0.00	0.20	-0.30	-0.10	0.00	0.20	0.40	82290	1
β	-0.20	0.60	-1.40	-0.50	-0.20	0.20	1.10	78341	1
σ_y^2	0.30	0.20	0.10	0.20	0.20	0.40	0.80	55486	1
October forecast average covering July Niño 3.4 SST anomalies									
α	0.00	0.20	-0.30	-0.10	0.00	0.10	0.40	84875	1
β	-0.10	0.60	-1.20	-0.50	-0.10	0.20	1.00	86033	1
σ_y^2	0.30	0.20	0.10	0.20	0.20	0.40	0.80	57932	1
September forecast average covering July Niño 3.4 SST anomalies									
α	0.00	0.20	-0.30	-0.10	0.00	0.20	0.40	79671	1
β	-0.40	0.70	-1.80	-0.80	-0.40	0.10	1.10	76768	1
σ_y^2	0.30	0.20	0.10	0.20	0.30	0.40	0.90	55337	1

Table 122: Call option prices for July Nino 3.4 SST conditioned on IRI ensemble forecasts released in May

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	25.24	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	25.35	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	25.45	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	25.55	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	25.66	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	25.76	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	25.87	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	25.97	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	26.07	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	26.17	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	26.28	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	26.38	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	26.49	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	26.59	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	26.70	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	26.80	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.91	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	27.01	0.00	0.00	0.00	0.00	0.01
-0.20	0.01	27.12	0.00	0.00	0.00	0.00	0.07
-0.10	0.01	27.22	0.00	0.00	0.00	0.00	0.13
0.00	0.01	27.32	0.00	0.00	0.00	0.00	0.21
0.10	0.02	27.42	0.00	0.00	0.00	0.00	0.28
0.20	0.03	27.53	0.00	0.00	0.00	0.00	0.37
0.30	0.05	27.63	0.00	0.00	0.00	0.00	0.46
0.40	0.07	27.73	0.00	0.00	0.00	0.07	0.57
0.50	0.11	27.84	0.00	0.00	0.00	0.16	0.67
0.60	0.15	27.94	0.00	0.00	0.00	0.24	0.78
0.70	0.20	28.05	0.00	0.00	0.08	0.33	0.89
0.80	0.25	28.16	0.00	0.00	0.17	0.43	1.00
0.90	0.31	28.26	0.00	0.00	0.24	0.52	1.00
1.00	0.37	28.36	0.00	0.03	0.32	0.61	1.00
1.10	0.43	28.47	0.00	0.10	0.40	0.71	1.00
1.20	0.49	28.57	0.00	0.16	0.48	0.80	1.00
1.30	0.54	28.67	0.00	0.22	0.56	0.89	1.00
1.40	0.59	28.78	0.00	0.29	0.64	0.99	1.00
1.50	0.63	28.88	0.00	0.35	0.72	1.00	1.00
1.60	0.68	28.99	0.00	0.42	0.80	1.00	1.00
1.70	0.71	29.09	0.00	0.48	0.88	1.00	1.00
1.80	0.74	29.19	0.00	0.54	0.96	1.00	1.00
1.90	0.77	29.29	0.00	0.59	1.00	1.00	1.00
2.00	0.80	29.40	0.00	0.66	1.00	1.00	1.00

Table 123: Call option prices for July Nino 3.4 SST conditioned on IRI ensemble forecasts released in April

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	24.96	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	25.08	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	25.20	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	25.32	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	25.43	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	25.55	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	25.67	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	25.79	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	25.90	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	26.02	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	26.14	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	26.26	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	26.37	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	26.49	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	26.61	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	26.72	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.84	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.96	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	27.08	0.00	0.00	0.00	0.00	0.00
-0.10	0.01	27.20	0.00	0.00	0.00	0.00	0.07
0.00	0.01	27.32	0.00	0.00	0.00	0.00	0.15
0.10	0.02	27.43	0.00	0.00	0.00	0.00	0.24
0.20	0.03	27.55	0.00	0.00	0.00	0.00	0.34
0.30	0.05	27.67	0.00	0.00	0.00	0.00	0.44
0.40	0.08	27.78	0.00	0.00	0.00	0.09	0.54
0.50	0.12	27.90	0.00	0.00	0.00	0.19	0.66
0.60	0.17	28.02	0.00	0.00	0.06	0.28	0.77
0.70	0.23	28.14	0.00	0.00	0.15	0.38	0.90
0.80	0.30	28.25	0.00	0.00	0.24	0.49	1.00
0.90	0.37	28.37	0.00	0.07	0.33	0.59	1.00
1.00	0.44	28.49	0.00	0.15	0.42	0.69	1.00
1.10	0.51	28.61	0.00	0.22	0.51	0.80	1.00
1.20	0.57	28.73	0.00	0.30	0.60	0.90	1.00
1.30	0.63	28.84	0.00	0.37	0.68	1.00	1.00
1.40	0.68	28.96	0.00	0.45	0.78	1.00	1.00
1.50	0.73	29.08	0.00	0.52	0.87	1.00	1.00
1.60	0.77	29.19	0.00	0.59	0.96	1.00	1.00
1.70	0.80	29.31	0.00	0.67	1.00	1.00	1.00
1.80	0.83	29.43	0.00	0.74	1.00	1.00	1.00
1.90	0.85	29.55	0.00	0.81	1.00	1.00	1.00
2.00	0.87	29.66	0.00	0.89	1.00	1.00	1.00

Table 124: Call option prices for July Nino 3.4 SST conditioned on IRI ensemble forecasts released in March

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.01	25.60	0.00	0.00	0.00	0.00	0.00
-1.90	0.01	25.69	0.00	0.00	0.00	0.00	0.00
-1.80	0.01	25.78	0.00	0.00	0.00	0.00	0.00
-1.70	0.01	25.86	0.00	0.00	0.00	0.00	0.00
-1.60	0.01	25.95	0.00	0.00	0.00	0.00	0.00
-1.50	0.01	26.04	0.00	0.00	0.00	0.00	0.00
-1.40	0.01	26.12	0.00	0.00	0.00	0.00	0.00
-1.30	0.01	26.21	0.00	0.00	0.00	0.00	0.00
-1.20	0.01	26.30	0.00	0.00	0.00	0.00	0.00
-1.10	0.01	26.38	0.00	0.00	0.00	0.00	0.00
-1.00	0.01	26.47	0.00	0.00	0.00	0.00	0.00
-0.90	0.01	26.55	0.00	0.00	0.00	0.00	0.00
-0.80	0.01	26.64	0.00	0.00	0.00	0.00	0.00
-0.70	0.01	26.73	0.00	0.00	0.00	0.00	0.00
-0.60	0.01	26.81	0.00	0.00	0.00	0.00	0.02
-0.50	0.01	26.90	0.00	0.00	0.00	0.00	0.05
-0.40	0.01	26.98	0.00	0.00	0.00	0.00	0.08
-0.30	0.01	27.07	0.00	0.00	0.00	0.00	0.13
-0.20	0.01	27.16	0.00	0.00	0.00	0.00	0.18
-0.10	0.02	27.24	0.00	0.00	0.00	0.00	0.23
0.00	0.02	27.33	0.00	0.00	0.00	0.00	0.30
0.10	0.03	27.41	0.00	0.00	0.00	0.00	0.36
0.20	0.04	27.50	0.00	0.00	0.00	0.00	0.42
0.30	0.06	27.59	0.00	0.00	0.00	0.00	0.52
0.40	0.07	27.67	0.00	0.00	0.00	0.05	0.59
0.50	0.10	27.76	0.00	0.00	0.00	0.12	0.70
0.60	0.13	27.84	0.00	0.00	0.00	0.20	0.78
0.70	0.17	27.93	0.00	0.00	0.00	0.27	0.89
0.80	0.21	28.02	0.00	0.00	0.06	0.35	1.00
0.90	0.25	28.11	0.00	0.00	0.13	0.43	1.00
1.00	0.30	28.19	0.00	0.00	0.20	0.51	1.00
1.10	0.34	28.28	0.00	0.00	0.26	0.60	1.00
1.20	0.38	28.36	0.00	0.00	0.32	0.67	1.00
1.30	0.43	28.45	0.00	0.02	0.39	0.76	1.00
1.40	0.47	28.54	0.00	0.07	0.45	0.85	1.00
1.50	0.51	28.62	0.00	0.11	0.52	0.92	1.00
1.60	0.55	28.71	0.00	0.16	0.59	1.00	1.00
1.70	0.58	28.79	0.00	0.21	0.65	1.00	1.00
1.80	0.61	28.88	0.00	0.25	0.72	1.00	1.00
1.90	0.64	28.97	0.00	0.31	0.78	1.00	1.00
2.00	0.67	29.05	0.00	0.34	0.85	1.00	1.00

Table 125: Call option prices for July Nino 3.4 SST conditioned on IRI ensemble forecasts released in February

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.07	26.57	0.00	0.00	0.00	0.00	1.00
-1.90	0.07	26.60	0.00	0.00	0.00	0.00	1.00
-1.80	0.06	26.64	0.00	0.00	0.00	0.00	0.96
-1.70	0.06	26.67	0.00	0.00	0.00	0.00	0.90
-1.60	0.06	26.71	0.00	0.00	0.00	0.00	0.85
-1.50	0.06	26.75	0.00	0.00	0.00	0.00	0.81
-1.40	0.05	26.78	0.00	0.00	0.00	0.00	0.76
-1.30	0.05	26.81	0.00	0.00	0.00	0.00	0.70
-1.20	0.04	26.85	0.00	0.00	0.00	0.00	0.65
-1.10	0.04	26.89	0.00	0.00	0.00	0.00	0.62
-1.00	0.04	26.92	0.00	0.00	0.00	0.00	0.57
-0.90	0.04	26.96	0.00	0.00	0.00	0.00	0.52
-0.80	0.03	26.99	0.00	0.00	0.00	0.00	0.50
-0.70	0.03	27.03	0.00	0.00	0.00	0.00	0.45
-0.60	0.03	27.06	0.00	0.00	0.00	0.00	0.44
-0.50	0.03	27.10	0.00	0.00	0.00	0.00	0.43
-0.40	0.03	27.14	0.00	0.00	0.00	0.00	0.40
-0.30	0.03	27.17	0.00	0.00	0.00	0.00	0.40
-0.20	0.03	27.20	0.00	0.00	0.00	0.00	0.39
-0.10	0.03	27.24	0.00	0.00	0.00	0.00	0.40
0.00	0.03	27.27	0.00	0.00	0.00	0.00	0.42
0.10	0.03	27.31	0.00	0.00	0.00	0.00	0.43
0.20	0.04	27.35	0.00	0.00	0.00	0.00	0.49
0.30	0.04	27.38	0.00	0.00	0.00	0.00	0.52
0.40	0.05	27.41	0.00	0.00	0.00	0.00	0.57
0.50	0.06	27.45	0.00	0.00	0.00	0.00	0.62
0.60	0.07	27.48	0.00	0.00	0.00	0.00	0.69
0.70	0.08	27.52	0.00	0.00	0.00	0.01	0.78
0.80	0.10	27.55	0.00	0.00	0.00	0.05	0.85
0.90	0.11	27.59	0.00	0.00	0.00	0.10	0.93
1.00	0.13	27.62	0.00	0.00	0.00	0.14	1.00
1.10	0.15	27.66	0.00	0.00	0.00	0.19	1.00
1.20	0.17	27.69	0.00	0.00	0.00	0.23	1.00
1.30	0.19	27.73	0.00	0.00	0.00	0.29	1.00
1.40	0.20	27.76	0.00	0.00	0.00	0.33	1.00
1.50	0.22	27.80	0.00	0.00	0.00	0.39	1.00
1.60	0.24	27.84	0.00	0.00	0.00	0.43	1.00
1.70	0.26	27.87	0.00	0.00	0.00	0.49	1.00
1.80	0.28	27.91	0.00	0.00	0.00	0.53	1.00
1.90	0.29	27.94	0.00	0.00	0.00	0.59	1.00
2.00	0.31	27.98	0.00	0.00	0.03	0.64	1.00

Table 126: Call option prices for July Nino 3.4 SST conditioned on IRI ensemble forecasts released in January

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.09	26.90	0.00	0.00	0.00	0.00	1.00
-1.90	0.09	26.92	0.00	0.00	0.00	0.00	1.00
-1.80	0.08	26.94	0.00	0.00	0.00	0.00	1.00
-1.70	0.08	26.96	0.00	0.00	0.00	0.00	0.99
-1.60	0.08	26.98	0.00	0.00	0.00	0.00	0.95
-1.50	0.07	27.00	0.00	0.00	0.00	0.00	0.87
-1.40	0.06	27.02	0.00	0.00	0.00	0.00	0.82
-1.30	0.06	27.04	0.00	0.00	0.00	0.00	0.77
-1.20	0.05	27.06	0.00	0.00	0.00	0.00	0.69
-1.10	0.05	27.08	0.00	0.00	0.00	0.00	0.65
-1.00	0.05	27.09	0.00	0.00	0.00	0.00	0.61
-0.90	0.04	27.11	0.00	0.00	0.00	0.00	0.57
-0.80	0.04	27.14	0.00	0.00	0.00	0.00	0.52
-0.70	0.04	27.15	0.00	0.00	0.00	0.00	0.49
-0.60	0.03	27.17	0.00	0.00	0.00	0.00	0.45
-0.50	0.03	27.19	0.00	0.00	0.00	0.00	0.42
-0.40	0.03	27.21	0.00	0.00	0.00	0.00	0.40
-0.30	0.03	27.23	0.00	0.00	0.00	0.00	0.38
-0.20	0.03	27.25	0.00	0.00	0.00	0.00	0.37
-0.10	0.03	27.27	0.00	0.00	0.00	0.00	0.37
0.00	0.03	27.29	0.00	0.00	0.00	0.00	0.37
0.10	0.03	27.31	0.00	0.00	0.00	0.00	0.38
0.20	0.03	27.33	0.00	0.00	0.00	0.00	0.40
0.30	0.04	27.35	0.00	0.00	0.00	0.00	0.45
0.40	0.04	27.37	0.00	0.00	0.00	0.00	0.48
0.50	0.05	27.39	0.00	0.00	0.00	0.00	0.52
0.60	0.05	27.40	0.00	0.00	0.00	0.00	0.58
0.70	0.06	27.43	0.00	0.00	0.00	0.00	0.64
0.80	0.07	27.45	0.00	0.00	0.00	0.00	0.71
0.90	0.08	27.47	0.00	0.00	0.00	0.00	0.77
1.00	0.09	27.49	0.00	0.00	0.00	0.02	0.85
1.10	0.10	27.50	0.00	0.00	0.00	0.05	0.92
1.20	0.12	27.52	0.00	0.00	0.00	0.08	1.00
1.30	0.13	27.54	0.00	0.00	0.00	0.12	1.00
1.40	0.14	27.56	0.00	0.00	0.00	0.16	1.00
1.50	0.16	27.58	0.00	0.00	0.00	0.19	1.00
1.60	0.17	27.60	0.00	0.00	0.00	0.23	1.00
1.70	0.18	27.62	0.00	0.00	0.00	0.27	1.00
1.80	0.20	27.64	0.00	0.00	0.00	0.31	1.00
1.90	0.21	27.66	0.00	0.00	0.00	0.34	1.00
2.00	0.22	27.68	0.00	0.00	0.00	0.37	1.00

Table 127: Call option prices for July Nino 3.4 SST conditioned on IRI ensemble forecasts released in December

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.11	27.05	0.00	0.00	0.00	0.00	1.00
-1.90	0.11	27.06	0.00	0.00	0.00	0.00	1.00
-1.80	0.10	27.07	0.00	0.00	0.00	0.00	1.00
-1.70	0.10	27.09	0.00	0.00	0.00	0.00	1.00
-1.60	0.09	27.10	0.00	0.00	0.00	0.00	1.00
-1.50	0.08	27.10	0.00	0.00	0.00	0.00	0.95
-1.40	0.08	27.12	0.00	0.00	0.00	0.00	0.91
-1.30	0.07	27.13	0.00	0.00	0.00	0.00	0.86
-1.20	0.07	27.15	0.00	0.00	0.00	0.00	0.81
-1.10	0.06	27.15	0.00	0.00	0.00	0.00	0.72
-1.00	0.06	27.17	0.00	0.00	0.00	0.00	0.69
-0.90	0.05	27.18	0.00	0.00	0.00	0.00	0.63
-0.80	0.05	27.20	0.00	0.00	0.00	0.00	0.58
-0.70	0.04	27.21	0.00	0.00	0.00	0.00	0.54
-0.60	0.04	27.22	0.00	0.00	0.00	0.00	0.50
-0.50	0.03	27.23	0.00	0.00	0.00	0.00	0.45
-0.40	0.03	27.24	0.00	0.00	0.00	0.00	0.42
-0.30	0.03	27.25	0.00	0.00	0.00	0.00	0.40
-0.20	0.03	27.26	0.00	0.00	0.00	0.00	0.38
-0.10	0.03	27.28	0.00	0.00	0.00	0.00	0.37
0.00	0.03	27.29	0.00	0.00	0.00	0.00	0.37
0.10	0.03	27.30	0.00	0.00	0.00	0.00	0.39
0.20	0.03	27.31	0.00	0.00	0.00	0.00	0.40
0.30	0.03	27.33	0.00	0.00	0.00	0.00	0.42
0.40	0.04	27.34	0.00	0.00	0.00	0.00	0.46
0.50	0.04	27.35	0.00	0.00	0.00	0.00	0.50
0.60	0.04	27.37	0.00	0.00	0.00	0.00	0.52
0.70	0.05	27.37	0.00	0.00	0.00	0.00	0.57
0.80	0.06	27.39	0.00	0.00	0.00	0.00	0.63
0.90	0.07	27.40	0.00	0.00	0.00	0.00	0.70
1.00	0.08	27.41	0.00	0.00	0.00	0.00	0.75
1.10	0.08	27.42	0.00	0.00	0.00	0.00	0.81
1.20	0.10	27.44	0.00	0.00	0.00	0.01	0.89
1.30	0.11	27.46	0.00	0.00	0.00	0.04	0.97
1.40	0.12	27.46	0.00	0.00	0.00	0.07	1.00
1.50	0.13	27.48	0.00	0.00	0.00	0.10	1.00
1.60	0.14	27.49	0.00	0.00	0.00	0.12	1.00
1.70	0.15	27.50	0.00	0.00	0.00	0.15	1.00
1.80	0.16	27.51	0.00	0.00	0.00	0.19	1.00
1.90	0.17	27.52	0.00	0.00	0.00	0.22	1.00
2.00	0.18	27.53	0.00	0.00	0.00	0.25	1.00

Table 128: Call option prices for July Nino 3.4 SST conditioned on IRI ensemble forecasts released in November

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.24	27.63	0.00	0.00	0.00	0.43	1.00
-1.90	0.23	27.61	0.00	0.00	0.00	0.39	1.00
-1.80	0.22	27.60	0.00	0.00	0.00	0.37	1.00
-1.70	0.21	27.58	0.00	0.00	0.00	0.32	1.00
-1.60	0.20	27.57	0.00	0.00	0.00	0.29	1.00
-1.50	0.18	27.55	0.00	0.00	0.00	0.25	1.00
-1.40	0.17	27.54	0.00	0.00	0.00	0.22	1.00
-1.30	0.16	27.52	0.00	0.00	0.00	0.18	1.00
-1.20	0.14	27.51	0.00	0.00	0.00	0.14	1.00
-1.10	0.13	27.49	0.00	0.00	0.00	0.11	1.00
-1.00	0.12	27.48	0.00	0.00	0.00	0.07	1.00
-0.90	0.10	27.46	0.00	0.00	0.00	0.04	0.95
-0.80	0.09	27.45	0.00	0.00	0.00	0.01	0.87
-0.70	0.08	27.43	0.00	0.00	0.00	0.00	0.78
-0.60	0.07	27.41	0.00	0.00	0.00	0.00	0.72
-0.50	0.06	27.40	0.00	0.00	0.00	0.00	0.65
-0.40	0.05	27.39	0.00	0.00	0.00	0.00	0.60
-0.30	0.05	27.38	0.00	0.00	0.00	0.00	0.54
-0.20	0.04	27.35	0.00	0.00	0.00	0.00	0.48
-0.10	0.04	27.34	0.00	0.00	0.00	0.00	0.44
0.00	0.03	27.32	0.00	0.00	0.00	0.00	0.40
0.10	0.03	27.31	0.00	0.00	0.00	0.00	0.40
0.20	0.03	27.29	0.00	0.00	0.00	0.00	0.39
0.30	0.03	27.28	0.00	0.00	0.00	0.00	0.38
0.40	0.03	27.26	0.00	0.00	0.00	0.00	0.39
0.50	0.03	27.25	0.00	0.00	0.00	0.00	0.40
0.60	0.03	27.23	0.00	0.00	0.00	0.00	0.42
0.70	0.04	27.21	0.00	0.00	0.00	0.00	0.46
0.80	0.04	27.20	0.00	0.00	0.00	0.00	0.50
0.90	0.04	27.19	0.00	0.00	0.00	0.00	0.54
1.00	0.05	27.17	0.00	0.00	0.00	0.00	0.59
1.10	0.05	27.16	0.00	0.00	0.00	0.00	0.65
1.20	0.06	27.14	0.00	0.00	0.00	0.00	0.70
1.30	0.06	27.13	0.00	0.00	0.00	0.00	0.76
1.40	0.07	27.11	0.00	0.00	0.00	0.00	0.83
1.50	0.07	27.10	0.00	0.00	0.00	0.00	0.89
1.60	0.08	27.08	0.00	0.00	0.00	0.00	0.97
1.70	0.09	27.07	0.00	0.00	0.00	0.00	1.00
1.80	0.10	27.05	0.00	0.00	0.00	0.00	1.00
1.90	0.10	27.04	0.00	0.00	0.00	0.00	1.00
2.00	0.11	27.02	0.00	0.00	0.00	0.00	1.00

Table 129: Call option prices for July Nino 3.4 SST conditioned on IRI ensemble forecasts released in October

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.21	27.55	0.00	0.00	0.00	0.33	1.00
-1.90	0.20	27.54	0.00	0.00	0.00	0.29	1.00
-1.80	0.19	27.53	0.00	0.00	0.00	0.26	1.00
-1.70	0.18	27.52	0.00	0.00	0.00	0.24	1.00
-1.60	0.17	27.50	0.00	0.00	0.00	0.19	1.00
-1.50	0.16	27.50	0.00	0.00	0.00	0.17	1.00
-1.40	0.15	27.49	0.00	0.00	0.00	0.15	1.00
-1.30	0.13	27.47	0.00	0.00	0.00	0.10	1.00
-1.20	0.12	27.46	0.00	0.00	0.00	0.07	1.00
-1.10	0.11	27.45	0.00	0.00	0.00	0.04	1.00
-1.00	0.10	27.43	0.00	0.00	0.00	0.02	0.93
-0.90	0.09	27.42	0.00	0.00	0.00	0.00	0.86
-0.80	0.08	27.41	0.00	0.00	0.00	0.00	0.79
-0.70	0.07	27.40	0.00	0.00	0.00	0.00	0.72
-0.60	0.06	27.39	0.00	0.00	0.00	0.00	0.64
-0.50	0.05	27.38	0.00	0.00	0.00	0.00	0.61
-0.40	0.05	27.37	0.00	0.00	0.00	0.00	0.55
-0.30	0.04	27.35	0.00	0.00	0.00	0.00	0.49
-0.20	0.04	27.34	0.00	0.00	0.00	0.00	0.46
-0.10	0.03	27.33	0.00	0.00	0.00	0.00	0.43
0.00	0.03	27.32	0.00	0.00	0.00	0.00	0.40
0.10	0.03	27.31	0.00	0.00	0.00	0.00	0.38
0.20	0.03	27.29	0.00	0.00	0.00	0.00	0.38
0.30	0.03	27.28	0.00	0.00	0.00	0.00	0.38
0.40	0.03	27.26	0.00	0.00	0.00	0.00	0.39
0.50	0.03	27.26	0.00	0.00	0.00	0.00	0.40
0.60	0.03	27.25	0.00	0.00	0.00	0.00	0.44
0.70	0.04	27.23	0.00	0.00	0.00	0.00	0.46
0.80	0.04	27.22	0.00	0.00	0.00	0.00	0.50
0.90	0.04	27.21	0.00	0.00	0.00	0.00	0.52
1.00	0.05	27.20	0.00	0.00	0.00	0.00	0.58
1.10	0.05	27.19	0.00	0.00	0.00	0.00	0.62
1.20	0.06	27.18	0.00	0.00	0.00	0.00	0.68
1.30	0.06	27.16	0.00	0.00	0.00	0.00	0.73
1.40	0.07	27.15	0.00	0.00	0.00	0.00	0.79
1.50	0.07	27.14	0.00	0.00	0.00	0.00	0.83
1.60	0.08	27.13	0.00	0.00	0.00	0.00	0.92
1.70	0.08	27.12	0.00	0.00	0.00	0.00	0.97
1.80	0.09	27.10	0.00	0.00	0.00	0.00	1.00
1.90	0.10	27.09	0.00	0.00	0.00	0.00	1.00
2.00	0.10	27.09	0.00	0.00	0.00	0.00	1.00

Table 130: Call option prices for July Nino 3.4 SST conditioned on IRI ensemble forecasts released in September

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.35	28.02	0.00	0.00	0.06	0.82	1.00
-1.90	0.34	27.98	0.00	0.00	0.03	0.77	1.00
-1.80	0.32	27.95	0.00	0.00	0.01	0.71	1.00
-1.70	0.31	27.92	0.00	0.00	0.00	0.66	1.00
-1.60	0.29	27.88	0.00	0.00	0.00	0.59	1.00
-1.50	0.27	27.84	0.00	0.00	0.00	0.54	1.00
-1.40	0.26	27.81	0.00	0.00	0.00	0.48	1.00
-1.30	0.24	27.77	0.00	0.00	0.00	0.42	1.00
-1.20	0.22	27.74	0.00	0.00	0.00	0.36	1.00
-1.10	0.20	27.70	0.00	0.00	0.00	0.31	1.00
-1.00	0.18	27.67	0.00	0.00	0.00	0.26	1.00
-0.90	0.16	27.64	0.00	0.00	0.00	0.20	1.00
-0.80	0.14	27.59	0.00	0.00	0.00	0.15	1.00
-0.70	0.12	27.56	0.00	0.00	0.00	0.10	0.99
-0.60	0.10	27.53	0.00	0.00	0.00	0.05	0.89
-0.50	0.09	27.49	0.00	0.00	0.00	0.00	0.80
-0.40	0.07	27.46	0.00	0.00	0.00	0.00	0.68
-0.30	0.06	27.42	0.00	0.00	0.00	0.00	0.61
-0.20	0.05	27.38	0.00	0.00	0.00	0.00	0.53
-0.10	0.04	27.35	0.00	0.00	0.00	0.00	0.49
0.00	0.03	27.31	0.00	0.00	0.00	0.00	0.43
0.10	0.03	27.28	0.00	0.00	0.00	0.00	0.40
0.20	0.03	27.24	0.00	0.00	0.00	0.00	0.37
0.30	0.03	27.21	0.00	0.00	0.00	0.00	0.37
0.40	0.03	27.17	0.00	0.00	0.00	0.00	0.37
0.50	0.03	27.14	0.00	0.00	0.00	0.00	0.37
0.60	0.03	27.10	0.00	0.00	0.00	0.00	0.38
0.70	0.03	27.07	0.00	0.00	0.00	0.00	0.42
0.80	0.03	27.03	0.00	0.00	0.00	0.00	0.48
0.90	0.03	27.00	0.00	0.00	0.00	0.00	0.50
1.00	0.04	26.96	0.00	0.00	0.00	0.00	0.55
1.10	0.04	26.93	0.00	0.00	0.00	0.00	0.61
1.20	0.05	26.89	0.00	0.00	0.00	0.00	0.66
1.30	0.05	26.85	0.00	0.00	0.00	0.00	0.74
1.40	0.06	26.82	0.00	0.00	0.00	0.00	0.79
1.50	0.06	26.79	0.00	0.00	0.00	0.00	0.86
1.60	0.07	26.75	0.00	0.00	0.00	0.00	0.94
1.70	0.07	26.72	0.00	0.00	0.00	0.00	1.00
1.80	0.07	26.68	0.00	0.00	0.00	0.00	1.00
1.90	0.08	26.64	0.00	0.00	0.00	0.00	1.00
2.00	0.08	26.61	0.00	0.00	0.00	0.00	1.00

Table 131: Put option prices for July Nino 3.4 SST conditioned on IRI ensemble forecasts released in May

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.77	25.24	0.00	0.58	1.00	1.00	1.00
-1.90	0.74	25.35	0.00	0.52	0.98	1.00	1.00
-1.80	0.71	25.45	0.00	0.46	0.89	1.00	1.00
-1.70	0.68	25.55	0.00	0.40	0.82	1.00	1.00
-1.60	0.64	25.66	0.00	0.34	0.74	1.00	1.00
-1.50	0.60	25.76	0.00	0.27	0.66	1.00	1.00
-1.40	0.55	25.87	0.00	0.21	0.58	0.94	1.00
-1.30	0.50	25.97	0.00	0.15	0.50	0.84	1.00
-1.20	0.44	26.07	0.00	0.08	0.42	0.75	1.00
-1.10	0.39	26.17	0.00	0.03	0.34	0.65	1.00
-1.00	0.33	26.28	0.00	0.00	0.26	0.56	1.00
-0.90	0.28	26.38	0.00	0.00	0.18	0.47	1.00
-0.80	0.22	26.49	0.00	0.00	0.10	0.38	0.98
-0.70	0.17	26.59	0.00	0.00	0.02	0.28	0.86
-0.60	0.13	26.70	0.00	0.00	0.00	0.19	0.74
-0.50	0.09	26.80	0.00	0.00	0.00	0.10	0.63
-0.40	0.06	26.91	0.00	0.00	0.00	0.01	0.51
-0.30	0.04	27.01	0.00	0.00	0.00	0.00	0.41
-0.20	0.02	27.12	0.00	0.00	0.00	0.00	0.32
-0.10	0.02	27.22	0.00	0.00	0.00	0.00	0.22
0.00	0.01	27.32	0.00	0.00	0.00	0.00	0.14
0.10	0.01	27.42	0.00	0.00	0.00	0.00	0.07
0.20	0.00	27.53	0.00	0.00	0.00	0.00	0.00
0.30	0.00	27.63	0.00	0.00	0.00	0.00	0.00
0.40	0.00	27.73	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.84	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.94	0.00	0.00	0.00	0.00	0.00
0.70	0.00	28.05	0.00	0.00	0.00	0.00	0.00
0.80	0.00	28.16	0.00	0.00	0.00	0.00	0.00
0.90	0.00	28.26	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.36	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.47	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.57	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.67	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.78	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.88	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.99	0.00	0.00	0.00	0.00	0.00
1.70	0.00	29.09	0.00	0.00	0.00	0.00	0.00
1.80	0.00	29.19	0.00	0.00	0.00	0.00	0.00
1.90	0.00	29.29	0.00	0.00	0.00	0.00	0.00
2.00	0.00	29.40	0.00	0.00	0.00	0.00	0.00

Table 132: Put option prices for July Nino 3.4 SST conditioned on IRI ensemble forecasts released in April

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.85	24.96	0.00	0.82	1.00	1.00	1.00
-1.90	0.83	25.08	0.00	0.75	1.00	1.00	1.00
-1.80	0.80	25.20	0.00	0.67	1.00	1.00	1.00
-1.70	0.77	25.32	0.00	0.59	0.99	1.00	1.00
-1.60	0.74	25.43	0.00	0.53	0.91	1.00	1.00
-1.50	0.70	25.55	0.00	0.45	0.82	1.00	1.00
-1.40	0.65	25.67	0.00	0.38	0.72	1.00	1.00
-1.30	0.59	25.79	0.00	0.31	0.64	0.96	1.00
-1.20	0.53	25.90	0.00	0.24	0.55	0.86	1.00
-1.10	0.47	26.02	0.00	0.16	0.46	0.76	1.00
-1.00	0.40	26.14	0.00	0.08	0.37	0.65	1.00
-0.90	0.33	26.26	0.00	0.01	0.28	0.55	1.00
-0.80	0.27	26.37	0.00	0.00	0.19	0.44	1.00
-0.70	0.20	26.49	0.00	0.00	0.10	0.34	0.87
-0.60	0.15	26.61	0.00	0.00	0.01	0.24	0.75
-0.50	0.10	26.72	0.00	0.00	0.00	0.14	0.63
-0.40	0.06	26.84	0.00	0.00	0.00	0.04	0.51
-0.30	0.04	26.96	0.00	0.00	0.00	0.00	0.40
-0.20	0.02	27.08	0.00	0.00	0.00	0.00	0.29
-0.10	0.01	27.20	0.00	0.00	0.00	0.00	0.20
0.00	0.01	27.32	0.00	0.00	0.00	0.00	0.09
0.10	0.00	27.43	0.00	0.00	0.00	0.00	0.01
0.20	0.00	27.55	0.00	0.00	0.00	0.00	0.00
0.30	0.00	27.67	0.00	0.00	0.00	0.00	0.00
0.40	0.00	27.78	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.90	0.00	0.00	0.00	0.00	0.00
0.60	0.00	28.02	0.00	0.00	0.00	0.00	0.00
0.70	0.00	28.14	0.00	0.00	0.00	0.00	0.00
0.80	0.00	28.25	0.00	0.00	0.00	0.00	0.00
0.90	0.00	28.37	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.49	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.61	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.73	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.84	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.96	0.00	0.00	0.00	0.00	0.00
1.50	0.00	29.08	0.00	0.00	0.00	0.00	0.00
1.60	0.00	29.19	0.00	0.00	0.00	0.00	0.00
1.70	0.00	29.31	0.00	0.00	0.00	0.00	0.00
1.80	0.00	29.43	0.00	0.00	0.00	0.00	0.00
1.90	0.00	29.55	0.00	0.00	0.00	0.00	0.00
2.00	0.00	29.66	0.00	0.00	0.00	0.00	0.00

Table 133: Put option prices for July Nino 3.4 SST conditioned on IRI ensemble forecasts released in March

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.63	25.60	0.00	0.26	0.77	1.00	1.00
-1.90	0.60	25.69	0.00	0.21	0.71	1.00	1.00
-1.80	0.57	25.78	0.00	0.16	0.64	1.00	1.00
-1.70	0.54	25.86	0.00	0.12	0.58	1.00	1.00
-1.60	0.51	25.95	0.00	0.07	0.51	0.95	1.00
-1.50	0.47	26.04	0.00	0.02	0.45	0.87	1.00
-1.40	0.43	26.12	0.00	0.00	0.38	0.79	1.00
-1.30	0.39	26.21	0.00	0.00	0.32	0.70	1.00
-1.20	0.34	26.30	0.00	0.00	0.25	0.61	1.00
-1.10	0.30	26.38	0.00	0.00	0.19	0.53	1.00
-1.00	0.26	26.47	0.00	0.00	0.12	0.45	1.00
-0.90	0.22	26.55	0.00	0.00	0.06	0.37	1.00
-0.80	0.18	26.64	0.00	0.00	0.00	0.29	0.95
-0.70	0.14	26.73	0.00	0.00	0.00	0.21	0.84
-0.60	0.11	26.81	0.00	0.00	0.00	0.13	0.73
-0.50	0.08	26.90	0.00	0.00	0.00	0.05	0.64
-0.40	0.06	26.98	0.00	0.00	0.00	0.00	0.54
-0.30	0.04	27.07	0.00	0.00	0.00	0.00	0.45
-0.20	0.03	27.16	0.00	0.00	0.00	0.00	0.37
-0.10	0.02	27.24	0.00	0.00	0.00	0.00	0.29
0.00	0.01	27.33	0.00	0.00	0.00	0.00	0.21
0.10	0.01	27.41	0.00	0.00	0.00	0.00	0.15
0.20	0.01	27.50	0.00	0.00	0.00	0.00	0.10
0.30	0.01	27.59	0.00	0.00	0.00	0.00	0.04
0.40	0.01	27.67	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.76	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.84	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.93	0.00	0.00	0.00	0.00	0.00
0.80	0.00	28.02	0.00	0.00	0.00	0.00	0.00
0.90	0.00	28.11	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.19	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.28	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.36	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.45	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.54	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.62	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.71	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.79	0.00	0.00	0.00	0.00	0.00
1.80	0.01	28.88	0.00	0.00	0.00	0.00	0.00
1.90	0.01	28.97	0.00	0.00	0.00	0.00	0.00
2.00	0.01	29.05	0.00	0.00	0.00	0.00	0.00

Table 134: Put option prices for July Nino 3.4 SST conditioned on IRI ensemble forecasts released in February

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.32	26.57	0.00	0.00	0.04	0.69	1.00
-1.90	0.31	26.60	0.00	0.00	0.01	0.64	1.00
-1.80	0.29	26.64	0.00	0.00	0.00	0.58	1.00
-1.70	0.27	26.67	0.00	0.00	0.00	0.53	1.00
-1.60	0.26	26.71	0.00	0.00	0.00	0.48	1.00
-1.50	0.24	26.75	0.00	0.00	0.00	0.43	1.00
-1.40	0.22	26.78	0.00	0.00	0.00	0.38	1.00
-1.30	0.20	26.81	0.00	0.00	0.00	0.33	1.00
-1.20	0.18	26.85	0.00	0.00	0.00	0.28	1.00
-1.10	0.16	26.89	0.00	0.00	0.00	0.23	1.00
-1.00	0.15	26.92	0.00	0.00	0.00	0.19	1.00
-0.90	0.13	26.96	0.00	0.00	0.00	0.13	1.00
-0.80	0.11	26.99	0.00	0.00	0.00	0.09	0.92
-0.70	0.10	27.03	0.00	0.00	0.00	0.04	0.83
-0.60	0.08	27.06	0.00	0.00	0.00	0.00	0.76
-0.50	0.07	27.10	0.00	0.00	0.00	0.00	0.69
-0.40	0.06	27.14	0.00	0.00	0.00	0.00	0.62
-0.30	0.05	27.17	0.00	0.00	0.00	0.00	0.55
-0.20	0.04	27.20	0.00	0.00	0.00	0.00	0.51
-0.10	0.04	27.24	0.00	0.00	0.00	0.00	0.44
0.00	0.03	27.27	0.00	0.00	0.00	0.00	0.41
0.10	0.03	27.31	0.00	0.00	0.00	0.00	0.39
0.20	0.03	27.35	0.00	0.00	0.00	0.00	0.38
0.30	0.03	27.38	0.00	0.00	0.00	0.00	0.36
0.40	0.02	27.41	0.00	0.00	0.00	0.00	0.36
0.50	0.03	27.45	0.00	0.00	0.00	0.00	0.38
0.60	0.03	27.48	0.00	0.00	0.00	0.00	0.37
0.70	0.03	27.52	0.00	0.00	0.00	0.00	0.40
0.80	0.03	27.55	0.00	0.00	0.00	0.00	0.42
0.90	0.03	27.59	0.00	0.00	0.00	0.00	0.45
1.00	0.03	27.62	0.00	0.00	0.00	0.00	0.51
1.10	0.04	27.66	0.00	0.00	0.00	0.00	0.53
1.20	0.04	27.69	0.00	0.00	0.00	0.00	0.57
1.30	0.04	27.73	0.00	0.00	0.00	0.00	0.60
1.40	0.04	27.76	0.00	0.00	0.00	0.00	0.67
1.50	0.05	27.80	0.00	0.00	0.00	0.00	0.72
1.60	0.05	27.84	0.00	0.00	0.00	0.00	0.78
1.70	0.06	27.87	0.00	0.00	0.00	0.00	0.82
1.80	0.06	27.91	0.00	0.00	0.00	0.00	0.87
1.90	0.06	27.94	0.00	0.00	0.00	0.00	0.93
2.00	0.06	27.98	0.00	0.00	0.00	0.00	0.98

Table 135: Put option prices for July Nino 3.4 SST conditioned on IRI ensemble forecasts released in January

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.23	26.90	0.00	0.00	0.00	0.39	1.00
-1.90	0.21	26.92	0.00	0.00	0.00	0.35	1.00
-1.80	0.20	26.94	0.00	0.00	0.00	0.31	1.00
-1.70	0.19	26.96	0.00	0.00	0.00	0.27	1.00
-1.60	0.17	26.98	0.00	0.00	0.00	0.24	1.00
-1.50	0.16	27.00	0.00	0.00	0.00	0.20	1.00
-1.40	0.15	27.02	0.00	0.00	0.00	0.16	1.00
-1.30	0.13	27.04	0.00	0.00	0.00	0.13	1.00
-1.20	0.12	27.06	0.00	0.00	0.00	0.09	1.00
-1.10	0.11	27.08	0.00	0.00	0.00	0.05	0.96
-1.00	0.10	27.09	0.00	0.00	0.00	0.02	0.90
-0.90	0.09	27.11	0.00	0.00	0.00	0.00	0.81
-0.80	0.07	27.14	0.00	0.00	0.00	0.00	0.74
-0.70	0.06	27.15	0.00	0.00	0.00	0.00	0.65
-0.60	0.06	27.17	0.00	0.00	0.00	0.00	0.61
-0.50	0.05	27.19	0.00	0.00	0.00	0.00	0.55
-0.40	0.04	27.21	0.00	0.00	0.00	0.00	0.50
-0.30	0.04	27.23	0.00	0.00	0.00	0.00	0.44
-0.20	0.03	27.25	0.00	0.00	0.00	0.00	0.41
-0.10	0.03	27.27	0.00	0.00	0.00	0.00	0.37
0.00	0.03	27.29	0.00	0.00	0.00	0.00	0.35
0.10	0.02	27.31	0.00	0.00	0.00	0.00	0.33
0.20	0.02	27.33	0.00	0.00	0.00	0.00	0.33
0.30	0.02	27.35	0.00	0.00	0.00	0.00	0.34
0.40	0.02	27.37	0.00	0.00	0.00	0.00	0.34
0.50	0.03	27.39	0.00	0.00	0.00	0.00	0.37
0.60	0.03	27.40	0.00	0.00	0.00	0.00	0.40
0.70	0.03	27.43	0.00	0.00	0.00	0.00	0.42
0.80	0.03	27.45	0.00	0.00	0.00	0.00	0.46
0.90	0.03	27.47	0.00	0.00	0.00	0.00	0.48
1.00	0.04	27.49	0.00	0.00	0.00	0.00	0.54
1.10	0.04	27.50	0.00	0.00	0.00	0.00	0.57
1.20	0.05	27.52	0.00	0.00	0.00	0.00	0.63
1.30	0.05	27.54	0.00	0.00	0.00	0.00	0.68
1.40	0.06	27.56	0.00	0.00	0.00	0.00	0.74
1.50	0.06	27.58	0.00	0.00	0.00	0.00	0.79
1.60	0.07	27.60	0.00	0.00	0.00	0.00	0.86
1.70	0.07	27.62	0.00	0.00	0.00	0.00	0.90
1.80	0.07	27.64	0.00	0.00	0.00	0.00	0.95
1.90	0.08	27.66	0.00	0.00	0.00	0.00	1.00
2.00	0.08	27.68	0.00	0.00	0.00	0.00	1.00

Table 136: Put option prices for July Nino 3.4 SST conditioned on IRI ensemble forecasts released in December

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.20	27.05	0.00	0.00	0.00	0.29	1.00
-1.90	0.18	27.06	0.00	0.00	0.00	0.25	1.00
-1.80	0.17	27.07	0.00	0.00	0.00	0.22	1.00
-1.70	0.16	27.09	0.00	0.00	0.00	0.18	1.00
-1.60	0.15	27.10	0.00	0.00	0.00	0.15	1.00
-1.50	0.14	27.10	0.00	0.00	0.00	0.13	1.00
-1.40	0.13	27.12	0.00	0.00	0.00	0.09	1.00
-1.30	0.12	27.13	0.00	0.00	0.00	0.06	1.00
-1.20	0.11	27.15	0.00	0.00	0.00	0.03	0.98
-1.10	0.10	27.15	0.00	0.00	0.00	0.01	0.90
-1.00	0.09	27.17	0.00	0.00	0.00	0.00	0.82
-0.90	0.08	27.18	0.00	0.00	0.00	0.00	0.77
-0.80	0.07	27.20	0.00	0.00	0.00	0.00	0.69
-0.70	0.06	27.21	0.00	0.00	0.00	0.00	0.63
-0.60	0.05	27.22	0.00	0.00	0.00	0.00	0.58
-0.50	0.04	27.23	0.00	0.00	0.00	0.00	0.53
-0.40	0.04	27.24	0.00	0.00	0.00	0.00	0.49
-0.30	0.04	27.25	0.00	0.00	0.00	0.00	0.44
-0.20	0.03	27.26	0.00	0.00	0.00	0.00	0.40
-0.10	0.03	27.28	0.00	0.00	0.00	0.00	0.38
0.00	0.03	27.29	0.00	0.00	0.00	0.00	0.34
0.10	0.02	27.30	0.00	0.00	0.00	0.00	0.35
0.20	0.02	27.31	0.00	0.00	0.00	0.00	0.33
0.30	0.02	27.33	0.00	0.00	0.00	0.00	0.35
0.40	0.02	27.34	0.00	0.00	0.00	0.00	0.34
0.50	0.03	27.35	0.00	0.00	0.00	0.00	0.37
0.60	0.03	27.37	0.00	0.00	0.00	0.00	0.39
0.70	0.03	27.37	0.00	0.00	0.00	0.00	0.43
0.80	0.03	27.39	0.00	0.00	0.00	0.00	0.47
0.90	0.04	27.40	0.00	0.00	0.00	0.00	0.50
1.00	0.04	27.41	0.00	0.00	0.00	0.00	0.54
1.10	0.05	27.42	0.00	0.00	0.00	0.00	0.60
1.20	0.05	27.44	0.00	0.00	0.00	0.00	0.65
1.30	0.06	27.46	0.00	0.00	0.00	0.00	0.70
1.40	0.06	27.46	0.00	0.00	0.00	0.00	0.77
1.50	0.07	27.48	0.00	0.00	0.00	0.00	0.80
1.60	0.07	27.49	0.00	0.00	0.00	0.00	0.90
1.70	0.08	27.50	0.00	0.00	0.00	0.00	0.93
1.80	0.09	27.51	0.00	0.00	0.00	0.00	1.00
1.90	0.09	27.52	0.00	0.00	0.00	0.00	1.00
2.00	0.10	27.53	0.00	0.00	0.00	0.00	1.00

Table 137: Put option prices for July Nino 3.4 SST conditioned on IRI ensemble forecasts released in November

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.12	27.63	0.00	0.00	0.00	0.00	1.00
-1.90	0.11	27.61	0.00	0.00	0.00	0.00	1.00
-1.80	0.11	27.60	0.00	0.00	0.00	0.00	1.00
-1.70	0.10	27.58	0.00	0.00	0.00	0.00	1.00
-1.60	0.09	27.57	0.00	0.00	0.00	0.00	1.00
-1.50	0.09	27.55	0.00	0.00	0.00	0.00	1.00
-1.40	0.08	27.54	0.00	0.00	0.00	0.00	0.99
-1.30	0.08	27.52	0.00	0.00	0.00	0.00	0.90
-1.20	0.07	27.51	0.00	0.00	0.00	0.00	0.83
-1.10	0.06	27.49	0.00	0.00	0.00	0.00	0.78
-1.00	0.06	27.48	0.00	0.00	0.00	0.00	0.72
-0.90	0.05	27.46	0.00	0.00	0.00	0.00	0.66
-0.80	0.05	27.45	0.00	0.00	0.00	0.00	0.60
-0.70	0.04	27.43	0.00	0.00	0.00	0.00	0.55
-0.60	0.04	27.41	0.00	0.00	0.00	0.00	0.51
-0.50	0.03	27.40	0.00	0.00	0.00	0.00	0.46
-0.40	0.03	27.39	0.00	0.00	0.00	0.00	0.41
-0.30	0.03	27.38	0.00	0.00	0.00	0.00	0.38
-0.20	0.03	27.35	0.00	0.00	0.00	0.00	0.37
-0.10	0.02	27.34	0.00	0.00	0.00	0.00	0.34
0.00	0.02	27.32	0.00	0.00	0.00	0.00	0.34
0.10	0.02	27.31	0.00	0.00	0.00	0.00	0.36
0.20	0.03	27.29	0.00	0.00	0.00	0.00	0.37
0.30	0.03	27.28	0.00	0.00	0.00	0.00	0.38
0.40	0.03	27.26	0.00	0.00	0.00	0.00	0.42
0.50	0.04	27.25	0.00	0.00	0.00	0.00	0.45
0.60	0.04	27.23	0.00	0.00	0.00	0.00	0.50
0.70	0.05	27.21	0.00	0.00	0.00	0.00	0.56
0.80	0.06	27.20	0.00	0.00	0.00	0.00	0.64
0.90	0.06	27.19	0.00	0.00	0.00	0.00	0.68
1.00	0.07	27.17	0.00	0.00	0.00	0.00	0.76
1.10	0.09	27.16	0.00	0.00	0.00	0.00	0.85
1.20	0.10	27.14	0.00	0.00	0.00	0.01	0.91
1.30	0.11	27.13	0.00	0.00	0.00	0.04	1.00
1.40	0.12	27.11	0.00	0.00	0.00	0.08	1.00
1.50	0.13	27.10	0.00	0.00	0.00	0.11	1.00
1.60	0.15	27.08	0.00	0.00	0.00	0.14	1.00
1.70	0.16	27.07	0.00	0.00	0.00	0.18	1.00
1.80	0.17	27.05	0.00	0.00	0.00	0.23	1.00
1.90	0.18	27.04	0.00	0.00	0.00	0.26	1.00
2.00	0.20	27.02	0.00	0.00	0.00	0.29	1.00

Table 138: Put option prices for July Nino 3.4 SST conditioned on IRI ensemble forecasts released in October

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.11	27.55	0.00	0.00	0.00	0.00	1.00
-1.90	0.11	27.54	0.00	0.00	0.00	0.00	1.00
-1.80	0.10	27.53	0.00	0.00	0.00	0.00	1.00
-1.70	0.10	27.52	0.00	0.00	0.00	0.00	1.00
-1.60	0.09	27.50	0.00	0.00	0.00	0.00	1.00
-1.50	0.08	27.50	0.00	0.00	0.00	0.00	0.97
-1.40	0.08	27.49	0.00	0.00	0.00	0.00	0.89
-1.30	0.07	27.47	0.00	0.00	0.00	0.00	0.84
-1.20	0.06	27.46	0.00	0.00	0.00	0.00	0.78
-1.10	0.06	27.45	0.00	0.00	0.00	0.00	0.73
-1.00	0.05	27.43	0.00	0.00	0.00	0.00	0.67
-0.90	0.05	27.42	0.00	0.00	0.00	0.00	0.61
-0.80	0.04	27.41	0.00	0.00	0.00	0.00	0.56
-0.70	0.04	27.40	0.00	0.00	0.00	0.00	0.52
-0.60	0.04	27.39	0.00	0.00	0.00	0.00	0.48
-0.50	0.03	27.38	0.00	0.00	0.00	0.00	0.43
-0.40	0.03	27.37	0.00	0.00	0.00	0.00	0.40
-0.30	0.03	27.35	0.00	0.00	0.00	0.00	0.36
-0.20	0.03	27.34	0.00	0.00	0.00	0.00	0.36
-0.10	0.02	27.33	0.00	0.00	0.00	0.00	0.35
0.00	0.02	27.32	0.00	0.00	0.00	0.00	0.34
0.10	0.02	27.31	0.00	0.00	0.00	0.00	0.34
0.20	0.03	27.29	0.00	0.00	0.00	0.00	0.35
0.30	0.03	27.28	0.00	0.00	0.00	0.00	0.38
0.40	0.03	27.26	0.00	0.00	0.00	0.00	0.41
0.50	0.03	27.26	0.00	0.00	0.00	0.00	0.44
0.60	0.04	27.25	0.00	0.00	0.00	0.00	0.48
0.70	0.04	27.23	0.00	0.00	0.00	0.00	0.52
0.80	0.05	27.22	0.00	0.00	0.00	0.00	0.59
0.90	0.06	27.21	0.00	0.00	0.00	0.00	0.64
1.00	0.07	27.20	0.00	0.00	0.00	0.00	0.73
1.10	0.08	27.19	0.00	0.00	0.00	0.00	0.76
1.20	0.09	27.18	0.00	0.00	0.00	0.00	0.84
1.30	0.10	27.16	0.00	0.00	0.00	0.00	0.92
1.40	0.11	27.15	0.00	0.00	0.00	0.02	1.00
1.50	0.12	27.14	0.00	0.00	0.00	0.06	1.00
1.60	0.13	27.13	0.00	0.00	0.00	0.08	1.00
1.70	0.14	27.12	0.00	0.00	0.00	0.11	1.00
1.80	0.15	27.10	0.00	0.00	0.00	0.15	1.00
1.90	0.16	27.09	0.00	0.00	0.00	0.18	1.00
2.00	0.17	27.09	0.00	0.00	0.00	0.21	1.00

Table 139: Put option prices for July Nino 3.4 SST conditioned on IRI ensemble forecasts released in September

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.10	28.02	0.00	0.00	0.00	0.00	1.00
-1.90	0.09	27.98	0.00	0.00	0.00	0.00	1.00
-1.80	0.09	27.95	0.00	0.00	0.00	0.00	1.00
-1.70	0.08	27.92	0.00	0.00	0.00	0.00	1.00
-1.60	0.08	27.88	0.00	0.00	0.00	0.00	1.00
-1.50	0.08	27.84	0.00	0.00	0.00	0.00	1.00
-1.40	0.07	27.81	0.00	0.00	0.00	0.00	0.98
-1.30	0.07	27.77	0.00	0.00	0.00	0.00	0.90
-1.20	0.06	27.74	0.00	0.00	0.00	0.00	0.83
-1.10	0.06	27.70	0.00	0.00	0.00	0.00	0.77
-1.00	0.05	27.67	0.00	0.00	0.00	0.00	0.71
-0.90	0.05	27.64	0.00	0.00	0.00	0.00	0.65
-0.80	0.04	27.59	0.00	0.00	0.00	0.00	0.61
-0.70	0.04	27.56	0.00	0.00	0.00	0.00	0.56
-0.60	0.04	27.53	0.00	0.00	0.00	0.00	0.49
-0.50	0.03	27.49	0.00	0.00	0.00	0.00	0.46
-0.40	0.03	27.46	0.00	0.00	0.00	0.00	0.42
-0.30	0.03	27.42	0.00	0.00	0.00	0.00	0.39
-0.20	0.03	27.38	0.00	0.00	0.00	0.00	0.37
-0.10	0.03	27.35	0.00	0.00	0.00	0.00	0.37
0.00	0.03	27.31	0.00	0.00	0.00	0.00	0.36
0.10	0.03	27.28	0.00	0.00	0.00	0.00	0.40
0.20	0.03	27.24	0.00	0.00	0.00	0.00	0.43
0.30	0.04	27.21	0.00	0.00	0.00	0.00	0.46
0.40	0.05	27.17	0.00	0.00	0.00	0.00	0.52
0.50	0.05	27.14	0.00	0.00	0.00	0.00	0.59
0.60	0.07	27.10	0.00	0.00	0.00	0.00	0.67
0.70	0.08	27.07	0.00	0.00	0.00	0.00	0.74
0.80	0.09	27.03	0.00	0.00	0.00	0.03	0.83
0.90	0.11	27.00	0.00	0.00	0.00	0.08	0.94
1.00	0.13	26.96	0.00	0.00	0.00	0.13	1.00
1.10	0.15	26.93	0.00	0.00	0.00	0.19	1.00
1.20	0.17	26.89	0.00	0.00	0.00	0.24	1.00
1.30	0.19	26.85	0.00	0.00	0.00	0.30	1.00
1.40	0.21	26.82	0.00	0.00	0.00	0.35	1.00
1.50	0.23	26.79	0.00	0.00	0.00	0.40	1.00
1.60	0.25	26.75	0.00	0.00	0.00	0.46	1.00
1.70	0.27	26.72	0.00	0.00	0.00	0.52	1.00
1.80	0.29	26.68	0.00	0.00	0.00	0.57	1.00
1.90	0.30	26.64	0.00	0.00	0.00	0.64	1.00
2.00	0.32	26.61	0.00	0.00	0.01	0.68	1.00

Appendix K: August Pricing

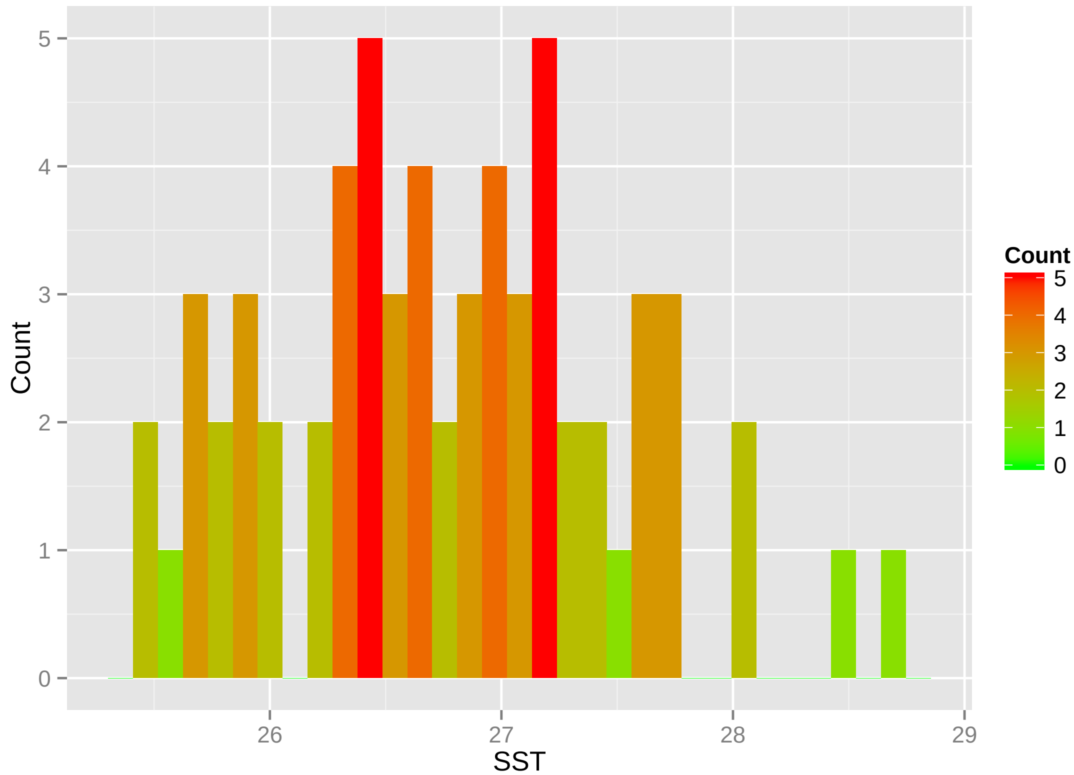


Figure 79: Histogram of August SST for Niño 3.4 ERSST.3b

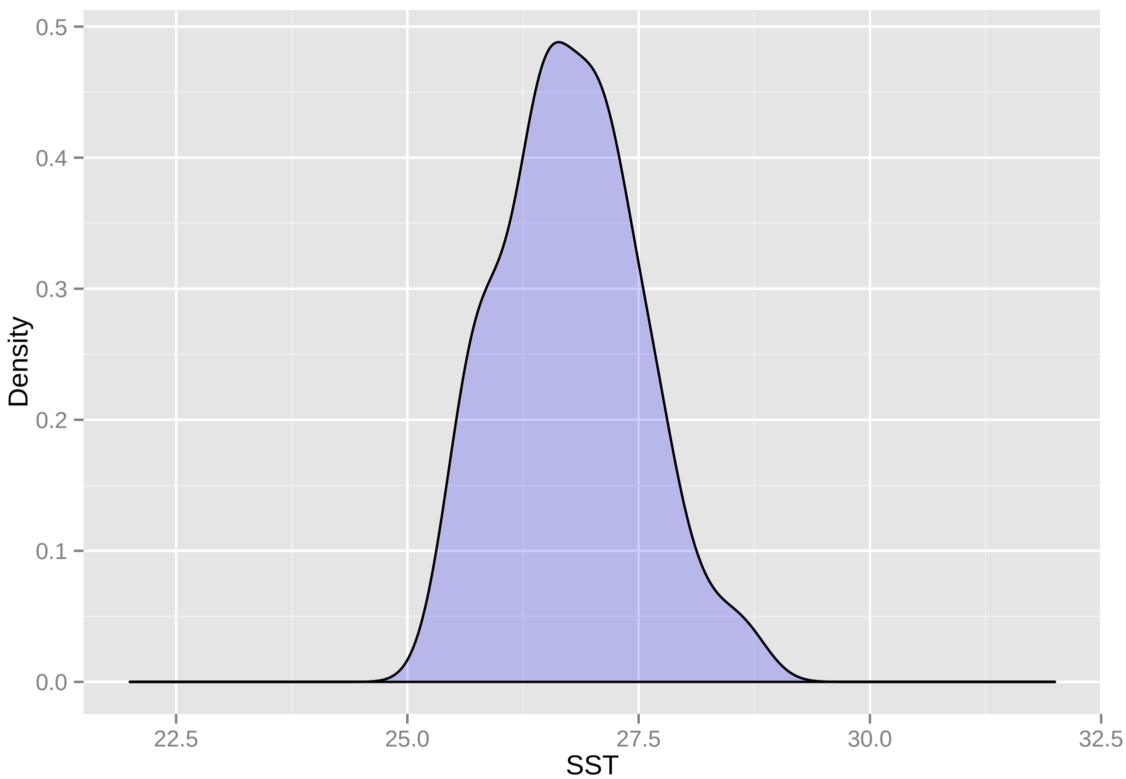


Figure 80: Kernel density estimate of August SST for Niño 3.4 ERSST.3b

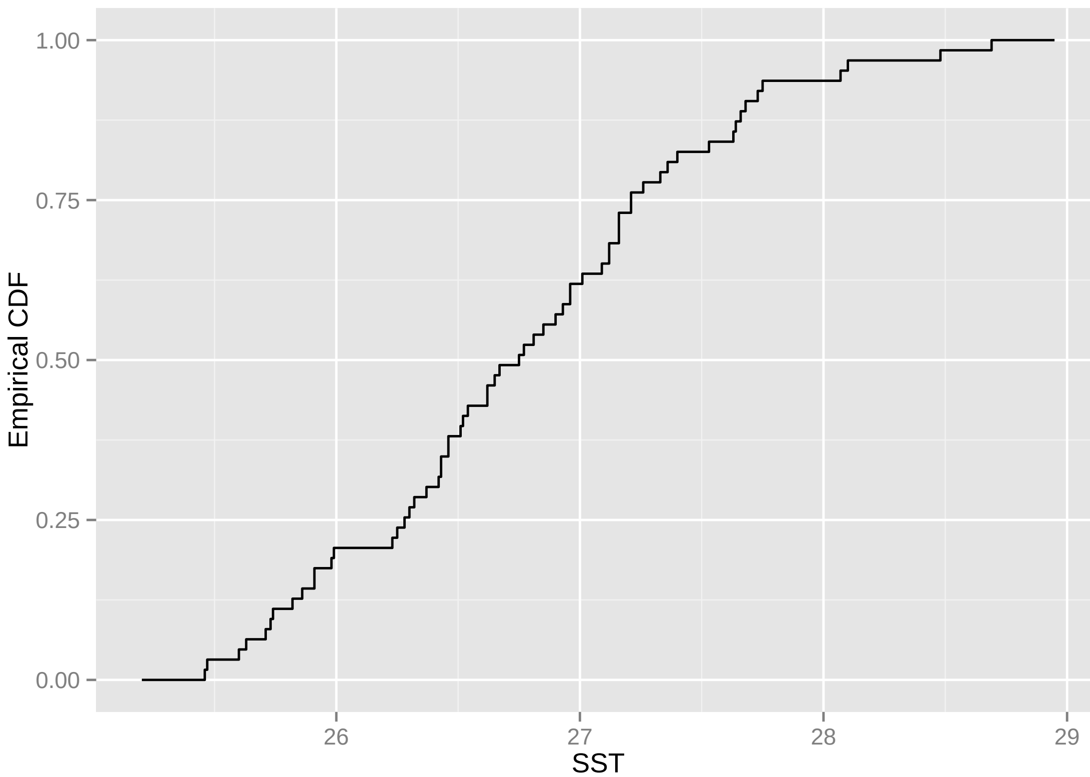


Figure 81: ECDF of August SST for Niño 3.4 ERSST.3b

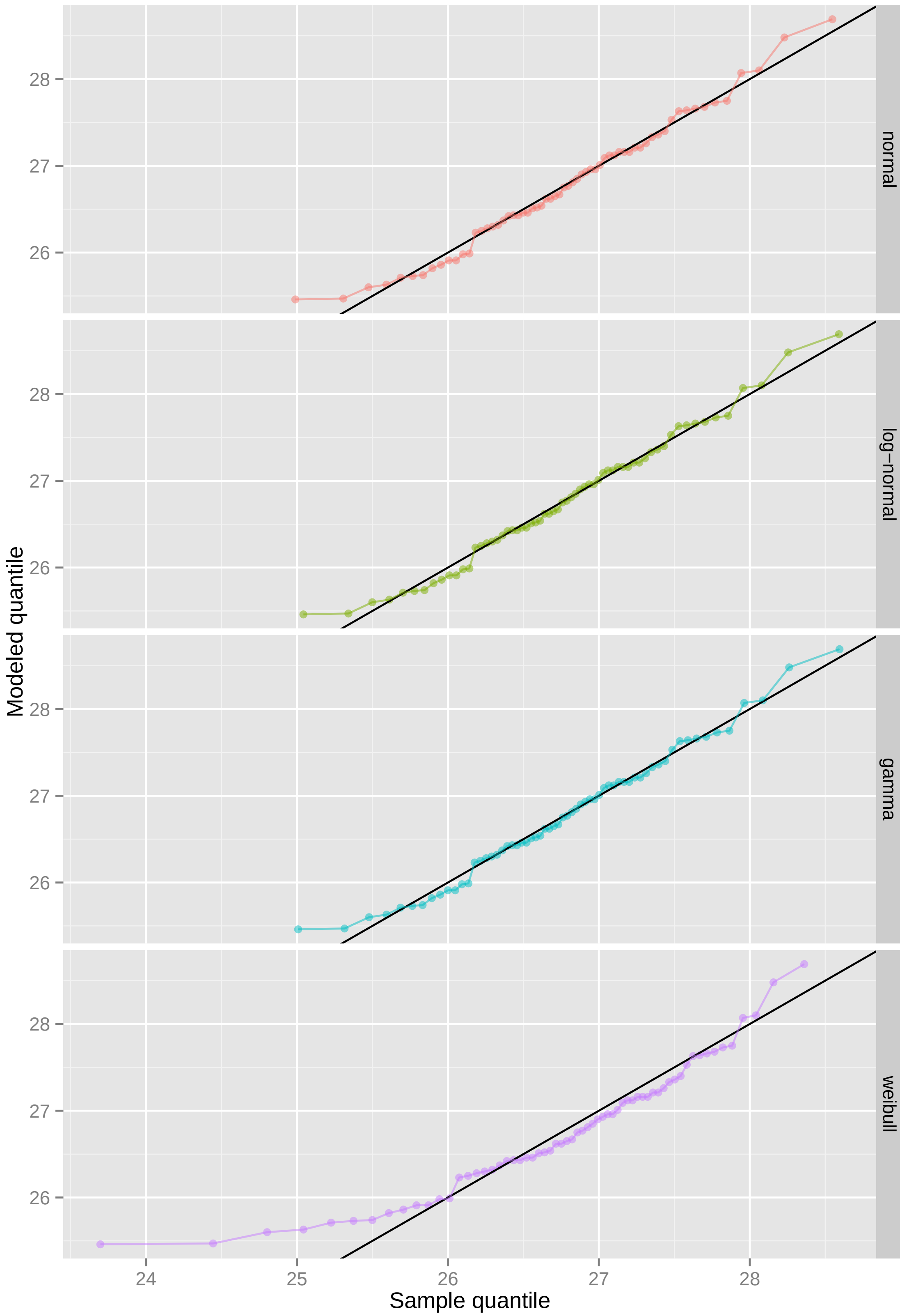


Figure 82: QQ plots of August SST for Niño 3.4 ERSST.3b compared to samples from various distributions (n=2 million)

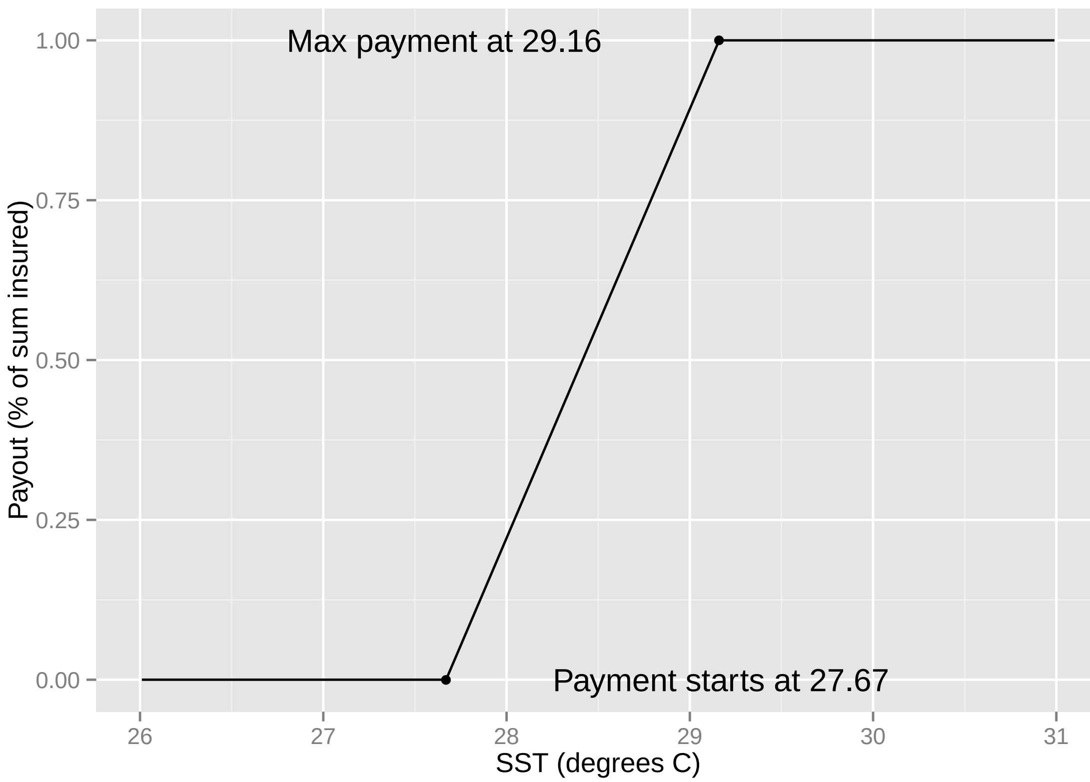


Figure 83: Payout function for call option on August SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations above the baseline

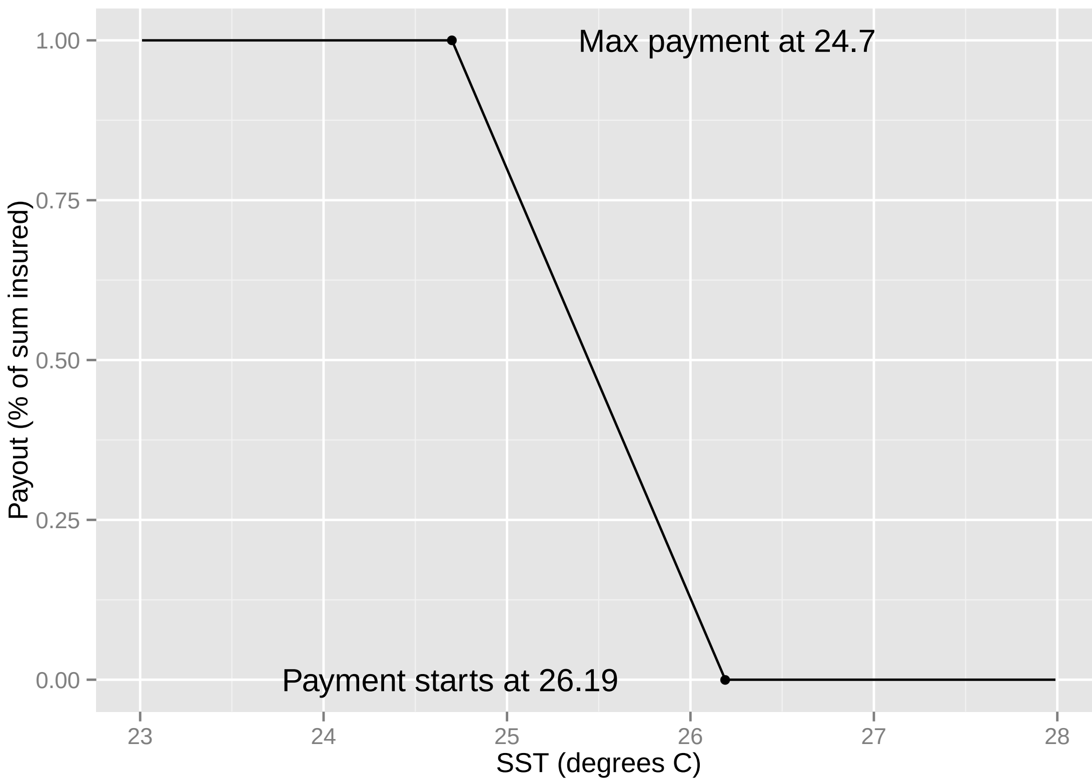


Figure 84: Payout function for put option on August SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

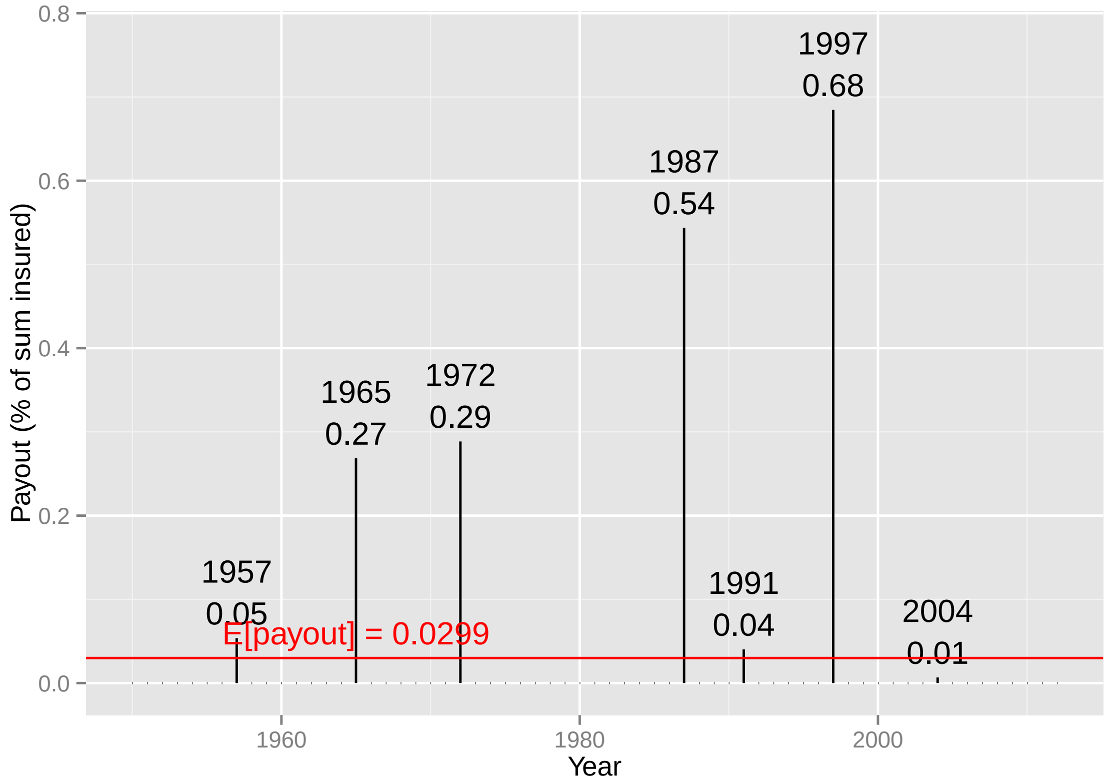


Figure 85: Historical burn on call option for August SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations above the baseline

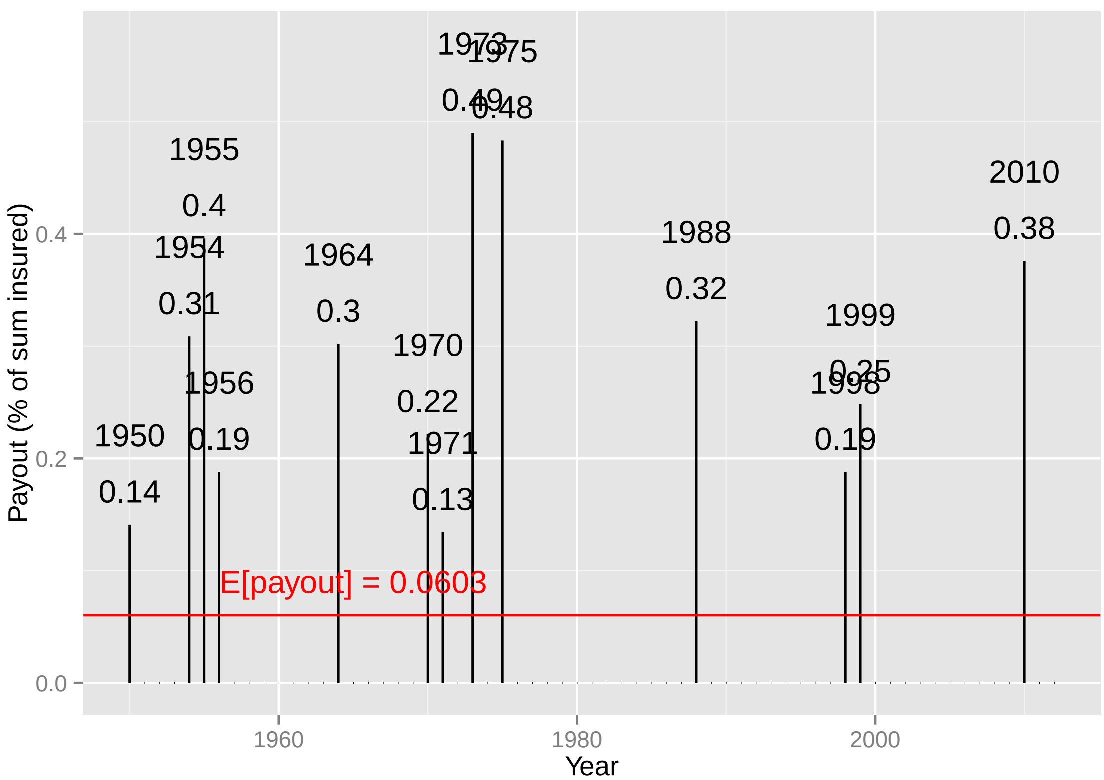


Figure 86: Historical burn on put option on August SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

Table 140: Bayesian regression linking August Niño 3.4 SST anomalies to average of relevant IRI ensemble forecasts

	mean	sd	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q	n_eff	Rhat
June forecast average covering August Niño 3.4 SST anomalies									
α	0.00	0.10	-0.20	-0.10	0.00	0.10	0.30	100140	1
β	1.20	0.30	0.60	1.00	1.20	1.30	1.80	98218	1
σ_y^2	0.20	0.10	0.10	0.10	0.20	0.20	0.50	56554	1
May forecast average covering August Niño 3.4 SST anomalies									
α	0.00	0.20	-0.30	-0.10	0.00	0.10	0.30	97464	1
β	1.20	0.50	0.20	0.90	1.20	1.50	2.20	93295	1
σ_y^2	0.30	0.20	0.10	0.20	0.30	0.40	0.80	57356	1
April forecast average covering August Niño 3.4 SST anomalies									
α	0.00	0.10	-0.30	-0.10	0.00	0.00	0.20	95865	1
β	1.50	0.50	0.60	1.20	1.50	1.80	2.40	92026	1
σ_y^2	0.20	0.10	0.10	0.10	0.20	0.30	0.60	58175	1
March forecast average covering August Niño 3.4 SST anomalies									
α	0.00	0.20	-0.40	-0.10	0.00	0.10	0.40	99884	1
β	1.20	0.70	-0.10	0.80	1.20	1.60	2.50	94706	1
σ_y^2	0.40	0.20	0.10	0.20	0.30	0.50	1.00	56753	1
February forecast average covering August Niño 3.4 SST anomalies									
α	0.00	0.20	-0.50	-0.20	0.00	0.10	0.40	96003	1
β	0.50	0.90	-1.40	0.00	0.50	1.10	2.30	88430	1
σ_y^2	0.60	0.50	0.20	0.40	0.50	0.70	1.80	52538	1
January forecast average covering August Niño 3.4 SST anomalies									
α	0.00	0.20	-0.40	-0.10	0.00	0.10	0.40	102565	1
β	0.40	0.90	-1.50	-0.20	0.40	1.00	2.30	93275	1
σ_y^2	0.60	0.40	0.20	0.30	0.50	0.70	1.50	59839	1
December forecast average covering August Niño 3.4 SST anomalies									
α	0.00	0.20	-0.50	-0.10	0.00	0.20	0.50	89100	1
β	0.00	1.00	-2.00	-0.60	0.00	0.70	2.10	86223	1
σ_y^2	0.60	0.40	0.20	0.30	0.50	0.70	1.50	56497	1
November forecast average covering August Niño 3.4 SST anomalies									
α	0.10	0.30	-0.40	-0.10	0.10	0.20	0.60	72923	1
β	-0.40	1.00	-2.30	-1.00	-0.40	0.20	1.60	71113	1
σ_y^2	0.60	0.40	0.20	0.30	0.50	0.70	1.50	53151	1
October forecast average covering August Niño 3.4 SST anomalies									
α	0.10	0.20	-0.40	-0.10	0.10	0.20	0.50	84695	1
β	-0.30	0.90	-2.10	-0.90	-0.30	0.20	1.50	82398	1
σ_y^2	0.60	0.40	0.20	0.30	0.50	0.70	1.50	56782	1

Table 141: Call option prices for August Nino 3.4 SST conditioned on IRI ensemble forecasts released in June

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	24.61	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	24.73	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.85	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.97	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	25.08	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	25.20	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	25.31	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	25.43	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	25.54	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.66	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.78	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.89	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	26.01	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	26.13	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	26.24	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	26.35	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.47	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.59	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.71	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	26.82	0.00	0.00	0.00	0.00	0.02
0.00	0.01	26.93	0.00	0.00	0.00	0.00	0.10
0.10	0.01	27.06	0.00	0.00	0.00	0.00	0.18
0.20	0.02	27.17	0.00	0.00	0.00	0.00	0.27
0.30	0.03	27.29	0.00	0.00	0.00	0.00	0.35
0.40	0.05	27.40	0.00	0.00	0.00	0.01	0.43
0.50	0.08	27.52	0.00	0.00	0.00	0.09	0.52
0.60	0.11	27.63	0.00	0.00	0.00	0.17	0.61
0.70	0.15	27.75	0.00	0.00	0.05	0.25	0.69
0.80	0.20	27.87	0.00	0.00	0.13	0.33	0.78
0.90	0.26	27.99	0.00	0.00	0.21	0.42	0.89
1.00	0.32	28.10	0.00	0.07	0.29	0.51	0.99
1.10	0.39	28.21	0.00	0.14	0.36	0.59	1.00
1.20	0.45	28.33	0.00	0.21	0.44	0.67	1.00
1.30	0.52	28.45	0.00	0.28	0.52	0.76	1.00
1.40	0.58	28.56	0.00	0.35	0.60	0.85	1.00
1.50	0.64	28.68	0.00	0.42	0.68	0.93	1.00
1.60	0.69	28.79	0.00	0.49	0.76	1.00	1.00
1.70	0.74	28.91	0.00	0.56	0.83	1.00	1.00
1.80	0.78	29.03	0.00	0.63	0.91	1.00	1.00
1.90	0.82	29.14	0.05	0.70	0.99	1.00	1.00
2.00	0.85	29.26	0.11	0.77	1.00	1.00	1.00

Table 142: Call option prices for August Nino 3.4 SST conditioned on IRI ensemble forecasts released in May

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	24.50	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	24.62	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.75	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.86	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.98	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	25.11	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	25.23	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	25.35	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	25.47	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.59	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.71	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.83	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.95	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	26.07	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	26.19	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	26.32	0.00	0.00	0.00	0.00	0.00
-0.40	0.01	26.44	0.00	0.00	0.00	0.00	0.00
-0.30	0.01	26.56	0.00	0.00	0.00	0.00	0.05
-0.20	0.01	26.67	0.00	0.00	0.00	0.00	0.11
-0.10	0.01	26.80	0.00	0.00	0.00	0.00	0.19
0.00	0.02	26.91	0.00	0.00	0.00	0.00	0.26
0.10	0.03	27.04	0.00	0.00	0.00	0.00	0.34
0.20	0.04	27.16	0.00	0.00	0.00	0.00	0.42
0.30	0.06	27.28	0.00	0.00	0.00	0.00	0.51
0.40	0.08	27.40	0.00	0.00	0.00	0.07	0.60
0.50	0.11	27.52	0.00	0.00	0.00	0.16	0.72
0.60	0.15	27.64	0.00	0.00	0.00	0.24	0.81
0.70	0.20	27.76	0.00	0.00	0.06	0.33	0.93
0.80	0.24	27.88	0.00	0.00	0.14	0.42	1.00
0.90	0.30	28.01	0.00	0.00	0.22	0.51	1.00
1.00	0.36	28.12	0.00	0.00	0.30	0.61	1.00
1.10	0.42	28.24	0.00	0.07	0.39	0.70	1.00
1.20	0.48	28.37	0.00	0.14	0.47	0.80	1.00
1.30	0.53	28.49	0.00	0.20	0.55	0.89	1.00
1.40	0.58	28.61	0.00	0.27	0.63	0.98	1.00
1.50	0.63	28.72	0.00	0.33	0.71	1.00	1.00
1.60	0.67	28.85	0.00	0.40	0.79	1.00	1.00
1.70	0.71	28.97	0.00	0.46	0.87	1.00	1.00
1.80	0.74	29.09	0.00	0.53	0.95	1.00	1.00
1.90	0.77	29.22	0.00	0.60	1.00	1.00	1.00
2.00	0.79	29.33	0.00	0.66	1.00	1.00	1.00

Table 143: Call option prices for August Nino 3.4 SST conditioned on IRI ensemble forecasts released in April

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	23.93	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	24.08	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.22	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.37	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.52	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.67	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	24.82	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	24.96	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	25.11	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.26	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.41	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.55	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.70	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.85	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	26.00	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	26.15	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.30	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.44	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.59	0.00	0.00	0.00	0.00	0.00
-0.10	0.01	26.74	0.00	0.00	0.00	0.00	0.06
0.00	0.01	26.89	0.00	0.00	0.00	0.00	0.15
0.10	0.02	27.03	0.00	0.00	0.00	0.00	0.24
0.20	0.03	27.19	0.00	0.00	0.00	0.00	0.35
0.30	0.05	27.33	0.00	0.00	0.00	0.00	0.46
0.40	0.08	27.48	0.00	0.00	0.00	0.09	0.57
0.50	0.12	27.63	0.00	0.00	0.00	0.19	0.69
0.60	0.18	27.77	0.00	0.00	0.07	0.30	0.81
0.70	0.24	27.92	0.00	0.00	0.17	0.41	0.94
0.80	0.32	28.07	0.00	0.02	0.27	0.52	1.00
0.90	0.40	28.22	0.00	0.11	0.37	0.63	1.00
1.00	0.48	28.37	0.00	0.20	0.47	0.74	1.00
1.10	0.55	28.51	0.00	0.28	0.57	0.85	1.00
1.20	0.62	28.67	0.00	0.37	0.67	0.97	1.00
1.30	0.68	28.81	0.00	0.46	0.77	1.00	1.00
1.40	0.74	28.96	0.00	0.54	0.87	1.00	1.00
1.50	0.78	29.11	0.00	0.62	0.97	1.00	1.00
1.60	0.82	29.26	0.00	0.71	1.00	1.00	1.00
1.70	0.85	29.40	0.00	0.79	1.00	1.00	1.00
1.80	0.87	29.55	0.00	0.87	1.00	1.00	1.00
1.90	0.89	29.70	0.07	0.95	1.00	1.00	1.00
2.00	0.91	29.85	0.11	1.00	1.00	1.00	1.00

Table 144: Call option prices for August Nino 3.4 SST conditioned on IRI ensemble forecasts released in March

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.01	24.57	0.00	0.00	0.00	0.00	0.00
-1.90	0.01	24.69	0.00	0.00	0.00	0.00	0.00
-1.80	0.01	24.81	0.00	0.00	0.00	0.00	0.00
-1.70	0.01	24.93	0.00	0.00	0.00	0.00	0.00
-1.60	0.01	25.05	0.00	0.00	0.00	0.00	0.00
-1.50	0.01	25.17	0.00	0.00	0.00	0.00	0.00
-1.40	0.01	25.28	0.00	0.00	0.00	0.00	0.00
-1.30	0.01	25.40	0.00	0.00	0.00	0.00	0.00
-1.20	0.01	25.52	0.00	0.00	0.00	0.00	0.00
-1.10	0.01	25.64	0.00	0.00	0.00	0.00	0.00
-1.00	0.01	25.75	0.00	0.00	0.00	0.00	0.00
-0.90	0.01	25.87	0.00	0.00	0.00	0.00	0.00
-0.80	0.01	25.99	0.00	0.00	0.00	0.00	0.02
-0.70	0.01	26.11	0.00	0.00	0.00	0.00	0.05
-0.60	0.01	26.23	0.00	0.00	0.00	0.00	0.08
-0.50	0.01	26.35	0.00	0.00	0.00	0.00	0.10
-0.40	0.01	26.47	0.00	0.00	0.00	0.00	0.14
-0.30	0.01	26.58	0.00	0.00	0.00	0.00	0.20
-0.20	0.02	26.70	0.00	0.00	0.00	0.00	0.26
-0.10	0.02	26.82	0.00	0.00	0.00	0.00	0.31
0.00	0.03	26.94	0.00	0.00	0.00	0.00	0.38
0.10	0.04	27.06	0.00	0.00	0.00	0.00	0.47
0.20	0.05	27.17	0.00	0.00	0.00	0.00	0.54
0.30	0.08	27.30	0.00	0.00	0.00	0.03	0.65
0.40	0.10	27.41	0.00	0.00	0.00	0.11	0.74
0.50	0.14	27.53	0.00	0.00	0.00	0.21	0.86
0.60	0.18	27.65	0.00	0.00	0.00	0.30	0.99
0.70	0.23	27.77	0.00	0.00	0.07	0.39	1.00
0.80	0.28	27.89	0.00	0.00	0.15	0.49	1.00
0.90	0.32	28.00	0.00	0.00	0.22	0.58	1.00
1.00	0.38	28.12	0.00	0.00	0.31	0.68	1.00
1.10	0.43	28.24	0.00	0.00	0.38	0.78	1.00
1.20	0.48	28.36	0.00	0.05	0.46	0.87	1.00
1.30	0.52	28.48	0.00	0.11	0.54	0.97	1.00
1.40	0.56	28.60	0.00	0.16	0.62	1.00	1.00
1.50	0.60	28.72	0.00	0.23	0.70	1.00	1.00
1.60	0.64	28.83	0.00	0.28	0.78	1.00	1.00
1.70	0.67	28.95	0.00	0.33	0.86	1.00	1.00
1.80	0.69	29.07	0.00	0.39	0.94	1.00	1.00
1.90	0.72	29.19	0.00	0.45	1.00	1.00	1.00
2.00	0.74	29.31	0.00	0.51	1.00	1.00	1.00

Table 145: Call option prices for August Nino 3.4 SST conditioned on IRI ensemble forecasts released in February

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.10	25.86	0.00	0.00	0.00	0.00	1.00
-1.90	0.10	25.91	0.00	0.00	0.00	0.00	1.00
-1.80	0.09	25.96	0.00	0.00	0.00	0.00	1.00
-1.70	0.09	26.01	0.00	0.00	0.00	0.00	1.00
-1.60	0.08	26.06	0.00	0.00	0.00	0.00	1.00
-1.50	0.08	26.12	0.00	0.00	0.00	0.00	1.00
-1.40	0.08	26.17	0.00	0.00	0.00	0.00	1.00
-1.30	0.07	26.22	0.00	0.00	0.00	0.00	1.00
-1.20	0.07	26.28	0.00	0.00	0.00	0.00	0.98
-1.10	0.06	26.32	0.00	0.00	0.00	0.00	0.91
-1.00	0.06	26.38	0.00	0.00	0.00	0.00	0.86
-0.90	0.05	26.42	0.00	0.00	0.00	0.00	0.79
-0.80	0.05	26.48	0.00	0.00	0.00	0.00	0.75
-0.70	0.05	26.53	0.00	0.00	0.00	0.00	0.71
-0.60	0.05	26.58	0.00	0.00	0.00	0.00	0.66
-0.50	0.04	26.63	0.00	0.00	0.00	0.00	0.62
-0.40	0.04	26.69	0.00	0.00	0.00	0.00	0.59
-0.30	0.04	26.74	0.00	0.00	0.00	0.00	0.57
-0.20	0.04	26.79	0.00	0.00	0.00	0.00	0.56
-0.10	0.05	26.84	0.00	0.00	0.00	0.00	0.58
0.00	0.05	26.88	0.00	0.00	0.00	0.00	0.59
0.10	0.05	26.95	0.00	0.00	0.00	0.00	0.63
0.20	0.06	26.99	0.00	0.00	0.00	0.00	0.66
0.30	0.07	27.05	0.00	0.00	0.00	0.00	0.73
0.40	0.08	27.09	0.00	0.00	0.00	0.00	0.81
0.50	0.10	27.15	0.00	0.00	0.00	0.03	0.90
0.60	0.12	27.20	0.00	0.00	0.00	0.08	0.98
0.70	0.13	27.25	0.00	0.00	0.00	0.13	1.00
0.80	0.15	27.30	0.00	0.00	0.00	0.19	1.00
0.90	0.17	27.35	0.00	0.00	0.00	0.25	1.00
1.00	0.20	27.40	0.00	0.00	0.00	0.31	1.00
1.10	0.22	27.45	0.00	0.00	0.00	0.37	1.00
1.20	0.24	27.51	0.00	0.00	0.00	0.44	1.00
1.30	0.27	27.56	0.00	0.00	0.00	0.50	1.00
1.40	0.29	27.62	0.00	0.00	0.00	0.57	1.00
1.50	0.31	27.67	0.00	0.00	0.00	0.64	1.00
1.60	0.33	27.72	0.00	0.00	0.04	0.70	1.00
1.70	0.34	27.77	0.00	0.00	0.07	0.77	1.00
1.80	0.36	27.82	0.00	0.00	0.10	0.85	1.00
1.90	0.38	27.87	0.00	0.00	0.14	0.91	1.00
2.00	0.40	27.93	0.00	0.00	0.17	0.98	1.00

Table 146: Call option prices for August Nino 3.4 SST conditioned on IRI ensemble forecasts released in January

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.13	26.13	0.00	0.00	0.00	0.00	1.00
-1.90	0.12	26.18	0.00	0.00	0.00	0.00	1.00
-1.80	0.12	26.21	0.00	0.00	0.00	0.00	1.00
-1.70	0.11	26.25	0.00	0.00	0.00	0.00	1.00
-1.60	0.11	26.29	0.00	0.00	0.00	0.00	1.00
-1.50	0.10	26.33	0.00	0.00	0.00	0.00	1.00
-1.40	0.10	26.36	0.00	0.00	0.00	0.00	1.00
-1.30	0.09	26.41	0.00	0.00	0.00	0.00	1.00
-1.20	0.09	26.45	0.00	0.00	0.00	0.00	1.00
-1.10	0.08	26.49	0.00	0.00	0.00	0.00	1.00
-1.00	0.07	26.52	0.00	0.00	0.00	0.00	0.93
-0.90	0.07	26.57	0.00	0.00	0.00	0.00	0.86
-0.80	0.06	26.61	0.00	0.00	0.00	0.00	0.80
-0.70	0.06	26.65	0.00	0.00	0.00	0.00	0.73
-0.60	0.05	26.69	0.00	0.00	0.00	0.00	0.69
-0.50	0.05	26.73	0.00	0.00	0.00	0.00	0.64
-0.40	0.05	26.77	0.00	0.00	0.00	0.00	0.60
-0.30	0.04	26.81	0.00	0.00	0.00	0.00	0.56
-0.20	0.04	26.85	0.00	0.00	0.00	0.00	0.54
-0.10	0.04	26.89	0.00	0.00	0.00	0.00	0.55
0.00	0.05	26.93	0.00	0.00	0.00	0.00	0.56
0.10	0.05	26.98	0.00	0.00	0.00	0.00	0.58
0.20	0.06	27.01	0.00	0.00	0.00	0.00	0.63
0.30	0.07	27.05	0.00	0.00	0.00	0.00	0.67
0.40	0.08	27.10	0.00	0.00	0.00	0.00	0.76
0.50	0.09	27.14	0.00	0.00	0.00	0.01	0.83
0.60	0.11	27.17	0.00	0.00	0.00	0.05	0.93
0.70	0.12	27.21	0.00	0.00	0.00	0.11	1.00
0.80	0.14	27.25	0.00	0.00	0.00	0.16	1.00
0.90	0.16	27.30	0.00	0.00	0.00	0.21	1.00
1.00	0.18	27.33	0.00	0.00	0.00	0.27	1.00
1.10	0.20	27.37	0.00	0.00	0.00	0.32	1.00
1.20	0.22	27.41	0.00	0.00	0.00	0.39	1.00
1.30	0.25	27.46	0.00	0.00	0.00	0.45	1.00
1.40	0.26	27.50	0.00	0.00	0.00	0.51	1.00
1.50	0.28	27.54	0.00	0.00	0.00	0.57	1.00
1.60	0.30	27.58	0.00	0.00	0.00	0.63	1.00
1.70	0.32	27.61	0.00	0.00	0.00	0.69	1.00
1.80	0.33	27.66	0.00	0.00	0.00	0.76	1.00
1.90	0.35	27.69	0.00	0.00	0.01	0.81	1.00
2.00	0.36	27.74	0.00	0.00	0.04	0.88	1.00

Table 147: Call option prices for August Nino 3.4 SST conditioned on IRI ensemble forecasts released in December

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.23	26.86	0.00	0.00	0.00	0.39	1.00
-1.90	0.22	26.87	0.00	0.00	0.00	0.36	1.00
-1.80	0.22	26.87	0.00	0.00	0.00	0.32	1.00
-1.70	0.21	26.87	0.00	0.00	0.00	0.28	1.00
-1.60	0.20	26.88	0.00	0.00	0.00	0.25	1.00
-1.50	0.19	26.88	0.00	0.00	0.00	0.21	1.00
-1.40	0.18	26.89	0.00	0.00	0.00	0.18	1.00
-1.30	0.17	26.89	0.00	0.00	0.00	0.14	1.00
-1.20	0.15	26.90	0.00	0.00	0.00	0.11	1.00
-1.10	0.14	26.90	0.00	0.00	0.00	0.08	1.00
-1.00	0.13	26.90	0.00	0.00	0.00	0.04	1.00
-0.90	0.12	26.91	0.00	0.00	0.00	0.02	1.00
-0.80	0.11	26.91	0.00	0.00	0.00	0.00	1.00
-0.70	0.10	26.91	0.00	0.00	0.00	0.00	1.00
-0.60	0.09	26.92	0.00	0.00	0.00	0.00	0.93
-0.50	0.08	26.93	0.00	0.00	0.00	0.00	0.83
-0.40	0.07	26.93	0.00	0.00	0.00	0.00	0.76
-0.30	0.06	26.93	0.00	0.00	0.00	0.00	0.69
-0.20	0.06	26.93	0.00	0.00	0.00	0.00	0.64
-0.10	0.05	26.94	0.00	0.00	0.00	0.00	0.59
0.00	0.05	26.94	0.00	0.00	0.00	0.00	0.56
0.10	0.05	26.95	0.00	0.00	0.00	0.00	0.59
0.20	0.05	26.95	0.00	0.00	0.00	0.00	0.58
0.30	0.05	26.96	0.00	0.00	0.00	0.00	0.63
0.40	0.06	26.96	0.00	0.00	0.00	0.00	0.67
0.50	0.07	26.96	0.00	0.00	0.00	0.00	0.72
0.60	0.08	26.97	0.00	0.00	0.00	0.00	0.80
0.70	0.09	26.97	0.00	0.00	0.00	0.00	0.87
0.80	0.10	26.98	0.00	0.00	0.00	0.00	0.97
0.90	0.11	26.98	0.00	0.00	0.00	0.01	1.00
1.00	0.12	26.99	0.00	0.00	0.00	0.05	1.00
1.10	0.14	26.99	0.00	0.00	0.00	0.08	1.00
1.20	0.15	26.99	0.00	0.00	0.00	0.11	1.00
1.30	0.16	27.00	0.00	0.00	0.00	0.16	1.00
1.40	0.17	27.00	0.00	0.00	0.00	0.20	1.00
1.50	0.19	27.01	0.00	0.00	0.00	0.24	1.00
1.60	0.20	27.01	0.00	0.00	0.00	0.28	1.00
1.70	0.21	27.01	0.00	0.00	0.00	0.32	1.00
1.80	0.22	27.02	0.00	0.00	0.00	0.35	1.00
1.90	0.23	27.02	0.00	0.00	0.00	0.40	1.00
2.00	0.24	27.03	0.00	0.00	0.00	0.44	1.00

Table 148: Call option prices for August Nino 3.4 SST conditioned on IRI ensemble forecasts released in November

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.38	27.75	0.00	0.00	0.06	0.99	1.00
-1.90	0.36	27.71	0.00	0.00	0.04	0.92	1.00
-1.80	0.35	27.67	0.00	0.00	0.00	0.86	1.00
-1.70	0.34	27.64	0.00	0.00	0.00	0.80	1.00
-1.60	0.33	27.61	0.00	0.00	0.00	0.74	1.00
-1.50	0.31	27.56	0.00	0.00	0.00	0.68	1.00
-1.40	0.29	27.53	0.00	0.00	0.00	0.62	1.00
-1.30	0.28	27.49	0.00	0.00	0.00	0.56	1.00
-1.20	0.26	27.45	0.00	0.00	0.00	0.50	1.00
-1.10	0.24	27.42	0.00	0.00	0.00	0.44	1.00
-1.00	0.22	27.38	0.00	0.00	0.00	0.38	1.00
-0.90	0.20	27.34	0.00	0.00	0.00	0.32	1.00
-0.80	0.18	27.30	0.00	0.00	0.00	0.26	1.00
-0.70	0.16	27.27	0.00	0.00	0.00	0.21	1.00
-0.60	0.14	27.23	0.00	0.00	0.00	0.15	1.00
-0.50	0.12	27.19	0.00	0.00	0.00	0.10	1.00
-0.40	0.11	27.16	0.00	0.00	0.00	0.05	0.92
-0.30	0.09	27.12	0.00	0.00	0.00	0.00	0.84
-0.20	0.08	27.09	0.00	0.00	0.00	0.00	0.75
-0.10	0.06	27.04	0.00	0.00	0.00	0.00	0.68
0.00	0.06	27.01	0.00	0.00	0.00	0.00	0.63
0.10	0.05	26.97	0.00	0.00	0.00	0.00	0.58
0.20	0.05	26.94	0.00	0.00	0.00	0.00	0.55
0.30	0.04	26.89	0.00	0.00	0.00	0.00	0.55
0.40	0.04	26.86	0.00	0.00	0.00	0.00	0.56
0.50	0.05	26.83	0.00	0.00	0.00	0.00	0.59
0.60	0.05	26.78	0.00	0.00	0.00	0.00	0.60
0.70	0.05	26.75	0.00	0.00	0.00	0.00	0.65
0.80	0.06	26.71	0.00	0.00	0.00	0.00	0.71
0.90	0.06	26.68	0.00	0.00	0.00	0.00	0.76
1.00	0.07	26.63	0.00	0.00	0.00	0.00	0.84
1.10	0.07	26.60	0.00	0.00	0.00	0.00	0.89
1.20	0.08	26.56	0.00	0.00	0.00	0.00	0.98
1.30	0.09	26.53	0.00	0.00	0.00	0.00	1.00
1.40	0.09	26.49	0.00	0.00	0.00	0.00	1.00
1.50	0.10	26.46	0.00	0.00	0.00	0.00	1.00
1.60	0.10	26.41	0.00	0.00	0.00	0.00	1.00
1.70	0.11	26.38	0.00	0.00	0.00	0.00	1.00
1.80	0.12	26.34	0.00	0.00	0.00	0.00	1.00
1.90	0.12	26.30	0.00	0.00	0.00	0.00	1.00
2.00	0.13	26.26	0.00	0.00	0.00	0.00	1.00

Table 149: Call option prices for August Nino 3.4 SST conditioned on IRI ensemble forecasts released in October

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.34	27.62	0.00	0.00	0.00	0.82	1.00
-1.90	0.33	27.58	0.00	0.00	0.00	0.77	1.00
-1.80	0.32	27.56	0.00	0.00	0.00	0.72	1.00
-1.70	0.30	27.52	0.00	0.00	0.00	0.65	1.00
-1.60	0.29	27.49	0.00	0.00	0.00	0.61	1.00
-1.50	0.27	27.46	0.00	0.00	0.00	0.55	1.00
-1.40	0.26	27.43	0.00	0.00	0.00	0.50	1.00
-1.30	0.24	27.39	0.00	0.00	0.00	0.44	1.00
-1.20	0.23	27.36	0.00	0.00	0.00	0.39	1.00
-1.10	0.21	27.33	0.00	0.00	0.00	0.34	1.00
-1.00	0.19	27.31	0.00	0.00	0.00	0.29	1.00
-0.90	0.17	27.27	0.00	0.00	0.00	0.24	1.00
-0.80	0.16	27.24	0.00	0.00	0.00	0.19	1.00
-0.70	0.14	27.21	0.00	0.00	0.00	0.14	1.00
-0.60	0.12	27.18	0.00	0.00	0.00	0.09	1.00
-0.50	0.10	27.14	0.00	0.00	0.00	0.05	0.92
-0.40	0.09	27.12	0.00	0.00	0.00	0.00	0.86
-0.30	0.08	27.09	0.00	0.00	0.00	0.00	0.77
-0.20	0.07	27.05	0.00	0.00	0.00	0.00	0.71
-0.10	0.06	27.03	0.00	0.00	0.00	0.00	0.65
0.00	0.05	26.99	0.00	0.00	0.00	0.00	0.60
0.10	0.05	26.96	0.00	0.00	0.00	0.00	0.57
0.20	0.05	26.93	0.00	0.00	0.00	0.00	0.57
0.30	0.04	26.89	0.00	0.00	0.00	0.00	0.53
0.40	0.04	26.86	0.00	0.00	0.00	0.00	0.55
0.50	0.05	26.83	0.00	0.00	0.00	0.00	0.56
0.60	0.05	26.80	0.00	0.00	0.00	0.00	0.61
0.70	0.05	26.77	0.00	0.00	0.00	0.00	0.67
0.80	0.06	26.74	0.00	0.00	0.00	0.00	0.70
0.90	0.06	26.71	0.00	0.00	0.00	0.00	0.76
1.00	0.07	26.68	0.00	0.00	0.00	0.00	0.82
1.10	0.07	26.64	0.00	0.00	0.00	0.00	0.88
1.20	0.08	26.62	0.00	0.00	0.00	0.00	0.97
1.30	0.08	26.58	0.00	0.00	0.00	0.00	1.00
1.40	0.09	26.55	0.00	0.00	0.00	0.00	1.00
1.50	0.10	26.52	0.00	0.00	0.00	0.00	1.00
1.60	0.10	26.49	0.00	0.00	0.00	0.00	1.00
1.70	0.11	26.46	0.00	0.00	0.00	0.00	1.00
1.80	0.12	26.43	0.00	0.00	0.00	0.00	1.00
1.90	0.12	26.40	0.00	0.00	0.00	0.00	1.00
2.00	0.13	26.37	0.00	0.00	0.00	0.00	1.00

Table 150: Put option prices for August Nino 3.4 SST conditioned on IRI ensemble forecasts released in June

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.84	24.61	0.05	0.75	1.00	1.00	1.00
-1.90	0.81	24.73	0.01	0.68	0.98	1.00	1.00
-1.80	0.77	24.85	0.00	0.61	0.90	1.00	1.00
-1.70	0.73	24.97	0.00	0.54	0.82	1.00	1.00
-1.60	0.68	25.08	0.00	0.47	0.75	1.00	1.00
-1.50	0.63	25.20	0.00	0.40	0.67	0.93	1.00
-1.40	0.57	25.31	0.00	0.34	0.59	0.85	1.00
-1.30	0.51	25.43	0.00	0.26	0.51	0.76	1.00
-1.20	0.45	25.54	0.00	0.20	0.44	0.68	1.00
-1.10	0.38	25.66	0.00	0.12	0.36	0.59	1.00
-1.00	0.32	25.78	0.00	0.05	0.28	0.50	1.00
-0.90	0.26	25.89	0.00	0.00	0.20	0.42	0.91
-0.80	0.20	26.01	0.00	0.00	0.12	0.34	0.81
-0.70	0.15	26.13	0.00	0.00	0.04	0.25	0.71
-0.60	0.11	26.24	0.00	0.00	0.00	0.16	0.61
-0.50	0.08	26.35	0.00	0.00	0.00	0.09	0.52
-0.40	0.05	26.47	0.00	0.00	0.00	0.00	0.44
-0.30	0.03	26.59	0.00	0.00	0.00	0.00	0.34
-0.20	0.02	26.71	0.00	0.00	0.00	0.00	0.25
-0.10	0.01	26.82	0.00	0.00	0.00	0.00	0.17
0.00	0.01	26.93	0.00	0.00	0.00	0.00	0.09
0.10	0.00	27.06	0.00	0.00	0.00	0.00	0.01
0.20	0.00	27.17	0.00	0.00	0.00	0.00	0.00
0.30	0.00	27.29	0.00	0.00	0.00	0.00	0.00
0.40	0.00	27.40	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.52	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.63	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.75	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.87	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.99	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.10	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.21	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.33	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.45	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.56	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.68	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.79	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.91	0.00	0.00	0.00	0.00	0.00
1.80	0.00	29.03	0.00	0.00	0.00	0.00	0.00
1.90	0.00	29.14	0.00	0.00	0.00	0.00	0.00
2.00	0.00	29.26	0.00	0.00	0.00	0.00	0.00

Table 151: Put option prices for August Nino 3.4 SST conditioned on IRI ensemble forecasts released in May

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.79	24.50	0.00	0.65	1.00	1.00	1.00
-1.90	0.77	24.62	0.00	0.59	1.00	1.00	1.00
-1.80	0.74	24.75	0.00	0.52	0.97	1.00	1.00
-1.70	0.71	24.86	0.00	0.46	0.89	1.00	1.00
-1.60	0.68	24.98	0.00	0.40	0.81	1.00	1.00
-1.50	0.63	25.11	0.00	0.33	0.73	1.00	1.00
-1.40	0.59	25.23	0.00	0.27	0.64	1.00	1.00
-1.30	0.54	25.35	0.00	0.20	0.56	0.93	1.00
-1.20	0.49	25.47	0.00	0.13	0.48	0.84	1.00
-1.10	0.43	25.59	0.00	0.07	0.40	0.74	1.00
-1.00	0.38	25.71	0.00	0.00	0.32	0.64	1.00
-0.90	0.32	25.83	0.00	0.00	0.24	0.55	1.00
-0.80	0.27	25.95	0.00	0.00	0.16	0.46	1.00
-0.70	0.21	26.07	0.00	0.00	0.08	0.37	0.99
-0.60	0.17	26.19	0.00	0.00	0.00	0.27	0.88
-0.50	0.12	26.32	0.00	0.00	0.00	0.18	0.76
-0.40	0.09	26.44	0.00	0.00	0.00	0.09	0.66
-0.30	0.06	26.56	0.00	0.00	0.00	0.00	0.56
-0.20	0.04	26.67	0.00	0.00	0.00	0.00	0.46
-0.10	0.03	26.80	0.00	0.00	0.00	0.00	0.36
0.00	0.02	26.91	0.00	0.00	0.00	0.00	0.29
0.10	0.01	27.04	0.00	0.00	0.00	0.00	0.20
0.20	0.01	27.16	0.00	0.00	0.00	0.00	0.11
0.30	0.01	27.28	0.00	0.00	0.00	0.00	0.05
0.40	0.01	27.40	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.52	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.64	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.76	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.88	0.00	0.00	0.00	0.00	0.00
0.90	0.00	28.01	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.12	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.24	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.37	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.49	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.61	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.72	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.85	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.97	0.00	0.00	0.00	0.00	0.00
1.80	0.00	29.09	0.00	0.00	0.00	0.00	0.00
1.90	0.00	29.22	0.00	0.00	0.00	0.00	0.00
2.00	0.00	29.33	0.00	0.00	0.00	0.00	0.00

Table 152: Put option prices for August Nino 3.4 SST conditioned on IRI ensemble forecasts released in April

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.91	23.93	0.09	1.00	1.00	1.00	1.00
-1.90	0.90	24.08	0.04	0.99	1.00	1.00	1.00
-1.80	0.88	24.22	0.00	0.91	1.00	1.00	1.00
-1.70	0.86	24.37	0.00	0.82	1.00	1.00	1.00
-1.60	0.83	24.52	0.00	0.74	1.00	1.00	1.00
-1.50	0.80	24.67	0.00	0.66	1.00	1.00	1.00
-1.40	0.76	24.82	0.00	0.57	0.92	1.00	1.00
-1.30	0.71	24.96	0.00	0.49	0.82	1.00	1.00
-1.20	0.65	25.11	0.00	0.41	0.72	1.00	1.00
-1.10	0.59	25.26	0.00	0.32	0.63	0.93	1.00
-1.00	0.52	25.41	0.00	0.23	0.53	0.82	1.00
-0.90	0.45	25.55	0.00	0.15	0.43	0.71	1.00
-0.80	0.37	25.70	0.00	0.06	0.33	0.60	1.00
-0.70	0.29	25.85	0.00	0.00	0.23	0.48	1.00
-0.60	0.22	26.00	0.00	0.00	0.13	0.37	0.91
-0.50	0.16	26.15	0.00	0.00	0.03	0.26	0.77
-0.40	0.11	26.30	0.00	0.00	0.00	0.15	0.64
-0.30	0.07	26.44	0.00	0.00	0.00	0.05	0.53
-0.20	0.04	26.59	0.00	0.00	0.00	0.00	0.42
-0.10	0.02	26.74	0.00	0.00	0.00	0.00	0.30
0.00	0.01	26.89	0.00	0.00	0.00	0.00	0.20
0.10	0.01	27.03	0.00	0.00	0.00	0.00	0.10
0.20	0.00	27.19	0.00	0.00	0.00	0.00	0.00
0.30	0.00	27.33	0.00	0.00	0.00	0.00	0.00
0.40	0.00	27.48	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.63	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.77	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.92	0.00	0.00	0.00	0.00	0.00
0.80	0.00	28.07	0.00	0.00	0.00	0.00	0.00
0.90	0.00	28.22	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.37	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.51	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.67	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.81	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.96	0.00	0.00	0.00	0.00	0.00
1.50	0.00	29.11	0.00	0.00	0.00	0.00	0.00
1.60	0.00	29.26	0.00	0.00	0.00	0.00	0.00
1.70	0.00	29.40	0.00	0.00	0.00	0.00	0.00
1.80	0.00	29.55	0.00	0.00	0.00	0.00	0.00
1.90	0.00	29.70	0.00	0.00	0.00	0.00	0.00
2.00	0.00	29.85	0.00	0.00	0.00	0.00	0.00

Table 153: Put option prices for August Nino 3.4 SST conditioned on IRI ensemble forecasts released in March

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.73	24.57	0.00	0.47	1.00	1.00	1.00
-1.90	0.71	24.69	0.00	0.41	1.00	1.00	1.00
-1.80	0.68	24.81	0.00	0.36	0.93	1.00	1.00
-1.70	0.66	24.93	0.00	0.30	0.85	1.00	1.00
-1.60	0.63	25.05	0.00	0.24	0.77	1.00	1.00
-1.50	0.59	25.17	0.00	0.19	0.69	1.00	1.00
-1.40	0.56	25.28	0.00	0.13	0.61	1.00	1.00
-1.30	0.52	25.40	0.00	0.07	0.53	0.99	1.00
-1.20	0.47	25.52	0.00	0.01	0.45	0.88	1.00
-1.10	0.42	25.64	0.00	0.00	0.37	0.78	1.00
-1.00	0.38	25.75	0.00	0.00	0.29	0.69	1.00
-0.90	0.33	25.87	0.00	0.00	0.22	0.59	1.00
-0.80	0.28	25.99	0.00	0.00	0.14	0.50	1.00
-0.70	0.23	26.11	0.00	0.00	0.05	0.39	1.00
-0.60	0.18	26.23	0.00	0.00	0.00	0.30	1.00
-0.50	0.14	26.35	0.00	0.00	0.00	0.21	0.88
-0.40	0.10	26.47	0.00	0.00	0.00	0.11	0.76
-0.30	0.08	26.58	0.00	0.00	0.00	0.02	0.66
-0.20	0.05	26.70	0.00	0.00	0.00	0.00	0.56
-0.10	0.04	26.82	0.00	0.00	0.00	0.00	0.45
0.00	0.03	26.94	0.00	0.00	0.00	0.00	0.36
0.10	0.02	27.06	0.00	0.00	0.00	0.00	0.28
0.20	0.01	27.17	0.00	0.00	0.00	0.00	0.22
0.30	0.01	27.30	0.00	0.00	0.00	0.00	0.15
0.40	0.01	27.41	0.00	0.00	0.00	0.00	0.10
0.50	0.01	27.53	0.00	0.00	0.00	0.00	0.05
0.60	0.01	27.65	0.00	0.00	0.00	0.00	0.01
0.70	0.01	27.77	0.00	0.00	0.00	0.00	0.00
0.80	0.01	27.89	0.00	0.00	0.00	0.00	0.00
0.90	0.01	28.00	0.00	0.00	0.00	0.00	0.00
1.00	0.01	28.12	0.00	0.00	0.00	0.00	0.00
1.10	0.01	28.24	0.00	0.00	0.00	0.00	0.00
1.20	0.01	28.36	0.00	0.00	0.00	0.00	0.00
1.30	0.01	28.48	0.00	0.00	0.00	0.00	0.00
1.40	0.01	28.60	0.00	0.00	0.00	0.00	0.00
1.50	0.01	28.72	0.00	0.00	0.00	0.00	0.00
1.60	0.01	28.83	0.00	0.00	0.00	0.00	0.00
1.70	0.01	28.95	0.00	0.00	0.00	0.00	0.00
1.80	0.01	29.07	0.00	0.00	0.00	0.00	0.00
1.90	0.01	29.19	0.00	0.00	0.00	0.00	0.00
2.00	0.01	29.31	0.00	0.00	0.00	0.00	0.00

Table 154: Put option prices for August Nino 3.4 SST conditioned on IRI ensemble forecasts released in February

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.41	25.86	0.00	0.00	0.23	1.00	1.00
-1.90	0.40	25.91	0.00	0.00	0.19	1.00	1.00
-1.80	0.39	25.96	0.00	0.00	0.16	0.93	1.00
-1.70	0.37	26.01	0.00	0.00	0.13	0.86	1.00
-1.60	0.35	26.06	0.00	0.00	0.09	0.80	1.00
-1.50	0.33	26.12	0.00	0.00	0.05	0.72	1.00
-1.40	0.32	26.17	0.00	0.00	0.02	0.66	1.00
-1.30	0.29	26.22	0.00	0.00	0.00	0.59	1.00
-1.20	0.27	26.28	0.00	0.00	0.00	0.53	1.00
-1.10	0.25	26.32	0.00	0.00	0.00	0.46	1.00
-1.00	0.23	26.38	0.00	0.00	0.00	0.39	1.00
-0.90	0.21	26.42	0.00	0.00	0.00	0.33	1.00
-0.80	0.18	26.48	0.00	0.00	0.00	0.28	1.00
-0.70	0.16	26.53	0.00	0.00	0.00	0.21	1.00
-0.60	0.14	26.58	0.00	0.00	0.00	0.16	1.00
-0.50	0.12	26.63	0.00	0.00	0.00	0.10	0.98
-0.40	0.10	26.69	0.00	0.00	0.00	0.04	0.90
-0.30	0.09	26.74	0.00	0.00	0.00	0.00	0.82
-0.20	0.07	26.79	0.00	0.00	0.00	0.00	0.73
-0.10	0.06	26.84	0.00	0.00	0.00	0.00	0.67
0.00	0.06	26.88	0.00	0.00	0.00	0.00	0.64
0.10	0.05	26.95	0.00	0.00	0.00	0.00	0.60
0.20	0.05	26.99	0.00	0.00	0.00	0.00	0.56
0.30	0.04	27.05	0.00	0.00	0.00	0.00	0.57
0.40	0.04	27.09	0.00	0.00	0.00	0.00	0.57
0.50	0.04	27.15	0.00	0.00	0.00	0.00	0.59
0.60	0.05	27.20	0.00	0.00	0.00	0.00	0.63
0.70	0.05	27.25	0.00	0.00	0.00	0.00	0.65
0.80	0.05	27.30	0.00	0.00	0.00	0.00	0.70
0.90	0.05	27.35	0.00	0.00	0.00	0.00	0.75
1.00	0.06	27.40	0.00	0.00	0.00	0.00	0.79
1.10	0.06	27.45	0.00	0.00	0.00	0.00	0.87
1.20	0.07	27.51	0.00	0.00	0.00	0.00	0.93
1.30	0.07	27.56	0.00	0.00	0.00	0.00	1.00
1.40	0.07	27.62	0.00	0.00	0.00	0.00	1.00
1.50	0.08	27.67	0.00	0.00	0.00	0.00	1.00
1.60	0.08	27.72	0.00	0.00	0.00	0.00	1.00
1.70	0.09	27.77	0.00	0.00	0.00	0.00	1.00
1.80	0.09	27.82	0.00	0.00	0.00	0.00	1.00
1.90	0.09	27.87	0.00	0.00	0.00	0.00	1.00
2.00	0.10	27.93	0.00	0.00	0.00	0.00	1.00

Table 155: Put option prices for August Nino 3.4 SST conditioned on IRI ensemble forecasts released in January

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.36	26.13	0.00	0.00	0.05	0.92	1.00
-1.90	0.35	26.18	0.00	0.00	0.01	0.86	1.00
-1.80	0.34	26.21	0.00	0.00	0.00	0.79	1.00
-1.70	0.32	26.25	0.00	0.00	0.00	0.72	1.00
-1.60	0.31	26.29	0.00	0.00	0.00	0.66	1.00
-1.50	0.29	26.33	0.00	0.00	0.00	0.60	1.00
-1.40	0.27	26.36	0.00	0.00	0.00	0.54	1.00
-1.30	0.25	26.41	0.00	0.00	0.00	0.49	1.00
-1.20	0.23	26.45	0.00	0.00	0.00	0.41	1.00
-1.10	0.21	26.49	0.00	0.00	0.00	0.35	1.00
-1.00	0.20	26.52	0.00	0.00	0.00	0.30	1.00
-0.90	0.17	26.57	0.00	0.00	0.00	0.24	1.00
-0.80	0.15	26.61	0.00	0.00	0.00	0.18	1.00
-0.70	0.13	26.65	0.00	0.00	0.00	0.13	1.00
-0.60	0.12	26.69	0.00	0.00	0.00	0.08	0.97
-0.50	0.10	26.73	0.00	0.00	0.00	0.03	0.89
-0.40	0.08	26.77	0.00	0.00	0.00	0.00	0.79
-0.30	0.07	26.81	0.00	0.00	0.00	0.00	0.71
-0.20	0.06	26.85	0.00	0.00	0.00	0.00	0.64
-0.10	0.05	26.89	0.00	0.00	0.00	0.00	0.59
0.00	0.05	26.93	0.00	0.00	0.00	0.00	0.54
0.10	0.04	26.98	0.00	0.00	0.00	0.00	0.50
0.20	0.04	27.01	0.00	0.00	0.00	0.00	0.52
0.30	0.04	27.05	0.00	0.00	0.00	0.00	0.52
0.40	0.04	27.10	0.00	0.00	0.00	0.00	0.53
0.50	0.04	27.14	0.00	0.00	0.00	0.00	0.57
0.60	0.05	27.17	0.00	0.00	0.00	0.00	0.60
0.70	0.05	27.21	0.00	0.00	0.00	0.00	0.65
0.80	0.05	27.25	0.00	0.00	0.00	0.00	0.70
0.90	0.06	27.30	0.00	0.00	0.00	0.00	0.76
1.00	0.06	27.33	0.00	0.00	0.00	0.00	0.85
1.10	0.07	27.37	0.00	0.00	0.00	0.00	0.92
1.20	0.08	27.41	0.00	0.00	0.00	0.00	0.98
1.30	0.08	27.46	0.00	0.00	0.00	0.00	1.00
1.40	0.09	27.50	0.00	0.00	0.00	0.00	1.00
1.50	0.09	27.54	0.00	0.00	0.00	0.00	1.00
1.60	0.10	27.58	0.00	0.00	0.00	0.00	1.00
1.70	0.10	27.61	0.00	0.00	0.00	0.00	1.00
1.80	0.11	27.66	0.00	0.00	0.00	0.00	1.00
1.90	0.11	27.69	0.00	0.00	0.00	0.00	1.00
2.00	0.12	27.74	0.00	0.00	0.00	0.00	1.00

Table 156: Put option prices for August Nino 3.4 SST conditioned on IRI ensemble forecasts released in December

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.25	26.86	0.00	0.00	0.00	0.50	1.00
-1.90	0.24	26.87	0.00	0.00	0.00	0.46	1.00
-1.80	0.23	26.87	0.00	0.00	0.00	0.41	1.00
-1.70	0.22	26.87	0.00	0.00	0.00	0.37	1.00
-1.60	0.21	26.88	0.00	0.00	0.00	0.33	1.00
-1.50	0.20	26.88	0.00	0.00	0.00	0.29	1.00
-1.40	0.19	26.89	0.00	0.00	0.00	0.24	1.00
-1.30	0.18	26.89	0.00	0.00	0.00	0.21	1.00
-1.20	0.17	26.90	0.00	0.00	0.00	0.16	1.00
-1.10	0.15	26.90	0.00	0.00	0.00	0.13	1.00
-1.00	0.14	26.90	0.00	0.00	0.00	0.09	1.00
-0.90	0.13	26.91	0.00	0.00	0.00	0.05	1.00
-0.80	0.11	26.91	0.00	0.00	0.00	0.02	1.00
-0.70	0.10	26.91	0.00	0.00	0.00	0.00	1.00
-0.60	0.09	26.92	0.00	0.00	0.00	0.00	0.92
-0.50	0.08	26.93	0.00	0.00	0.00	0.00	0.82
-0.40	0.07	26.93	0.00	0.00	0.00	0.00	0.75
-0.30	0.06	26.93	0.00	0.00	0.00	0.00	0.67
-0.20	0.05	26.93	0.00	0.00	0.00	0.00	0.61
-0.10	0.05	26.94	0.00	0.00	0.00	0.00	0.57
0.00	0.05	26.94	0.00	0.00	0.00	0.00	0.56
0.10	0.04	26.95	0.00	0.00	0.00	0.00	0.54
0.20	0.05	26.95	0.00	0.00	0.00	0.00	0.55
0.30	0.05	26.96	0.00	0.00	0.00	0.00	0.60
0.40	0.05	26.96	0.00	0.00	0.00	0.00	0.62
0.50	0.06	26.96	0.00	0.00	0.00	0.00	0.69
0.60	0.07	26.97	0.00	0.00	0.00	0.00	0.74
0.70	0.08	26.97	0.00	0.00	0.00	0.00	0.85
0.80	0.08	26.98	0.00	0.00	0.00	0.00	0.92
0.90	0.09	26.98	0.00	0.00	0.00	0.00	1.00
1.00	0.11	26.99	0.00	0.00	0.00	0.00	1.00
1.10	0.12	26.99	0.00	0.00	0.00	0.00	1.00
1.20	0.13	26.99	0.00	0.00	0.00	0.03	1.00
1.30	0.14	27.00	0.00	0.00	0.00	0.06	1.00
1.40	0.15	27.00	0.00	0.00	0.00	0.10	1.00
1.50	0.16	27.01	0.00	0.00	0.00	0.13	1.00
1.60	0.17	27.01	0.00	0.00	0.00	0.16	1.00
1.70	0.18	27.01	0.00	0.00	0.00	0.20	1.00
1.80	0.19	27.02	0.00	0.00	0.00	0.23	1.00
1.90	0.20	27.02	0.00	0.00	0.00	0.27	1.00
2.00	0.21	27.03	0.00	0.00	0.00	0.30	1.00

Table 157: Put option prices for August Nino 3.4 SST conditioned on IRI ensemble forecasts released in November

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.14	27.75	0.00	0.00	0.00	0.00	1.00
-1.90	0.14	27.71	0.00	0.00	0.00	0.00	1.00
-1.80	0.13	27.67	0.00	0.00	0.00	0.00	1.00
-1.70	0.13	27.64	0.00	0.00	0.00	0.00	1.00
-1.60	0.12	27.61	0.00	0.00	0.00	0.00	1.00
-1.50	0.11	27.56	0.00	0.00	0.00	0.00	1.00
-1.40	0.11	27.53	0.00	0.00	0.00	0.00	1.00
-1.30	0.10	27.49	0.00	0.00	0.00	0.00	1.00
-1.20	0.09	27.45	0.00	0.00	0.00	0.00	1.00
-1.10	0.09	27.42	0.00	0.00	0.00	0.00	1.00
-1.00	0.08	27.38	0.00	0.00	0.00	0.00	1.00
-0.90	0.08	27.34	0.00	0.00	0.00	0.00	0.94
-0.80	0.07	27.30	0.00	0.00	0.00	0.00	0.87
-0.70	0.06	27.27	0.00	0.00	0.00	0.00	0.80
-0.60	0.06	27.23	0.00	0.00	0.00	0.00	0.74
-0.50	0.05	27.19	0.00	0.00	0.00	0.00	0.66
-0.40	0.05	27.16	0.00	0.00	0.00	0.00	0.63
-0.30	0.04	27.12	0.00	0.00	0.00	0.00	0.58
-0.20	0.04	27.09	0.00	0.00	0.00	0.00	0.54
-0.10	0.04	27.04	0.00	0.00	0.00	0.00	0.52
0.00	0.04	27.01	0.00	0.00	0.00	0.00	0.52
0.10	0.04	26.97	0.00	0.00	0.00	0.00	0.53
0.20	0.04	26.94	0.00	0.00	0.00	0.00	0.55
0.30	0.05	26.89	0.00	0.00	0.00	0.00	0.60
0.40	0.06	26.86	0.00	0.00	0.00	0.00	0.65
0.50	0.07	26.83	0.00	0.00	0.00	0.00	0.71
0.60	0.08	26.78	0.00	0.00	0.00	0.00	0.79
0.70	0.10	26.75	0.00	0.00	0.00	0.02	0.89
0.80	0.11	26.71	0.00	0.00	0.00	0.07	0.99
0.90	0.13	26.68	0.00	0.00	0.00	0.11	1.00
1.00	0.15	26.63	0.00	0.00	0.00	0.18	1.00
1.10	0.17	26.60	0.00	0.00	0.00	0.22	1.00
1.20	0.19	26.56	0.00	0.00	0.00	0.29	1.00
1.30	0.21	26.53	0.00	0.00	0.00	0.34	1.00
1.40	0.23	26.49	0.00	0.00	0.00	0.40	1.00
1.50	0.25	26.46	0.00	0.00	0.00	0.47	1.00
1.60	0.27	26.41	0.00	0.00	0.00	0.52	1.00
1.70	0.28	26.38	0.00	0.00	0.00	0.58	1.00
1.80	0.30	26.34	0.00	0.00	0.00	0.64	1.00
1.90	0.31	26.30	0.00	0.00	0.00	0.71	1.00
2.00	0.33	26.26	0.00	0.00	0.00	0.77	1.00

Table 158: Put option prices for August Nino 3.4 SST conditioned on IRI ensemble forecasts released in October

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.14	27.62	0.00	0.00	0.00	0.00	1.00
-1.90	0.13	27.58	0.00	0.00	0.00	0.00	1.00
-1.80	0.13	27.56	0.00	0.00	0.00	0.00	1.00
-1.70	0.12	27.52	0.00	0.00	0.00	0.00	1.00
-1.60	0.12	27.49	0.00	0.00	0.00	0.00	1.00
-1.50	0.11	27.46	0.00	0.00	0.00	0.00	1.00
-1.40	0.10	27.43	0.00	0.00	0.00	0.00	1.00
-1.30	0.10	27.39	0.00	0.00	0.00	0.00	1.00
-1.20	0.09	27.36	0.00	0.00	0.00	0.00	1.00
-1.10	0.08	27.33	0.00	0.00	0.00	0.00	1.00
-1.00	0.08	27.31	0.00	0.00	0.00	0.00	0.97
-0.90	0.07	27.27	0.00	0.00	0.00	0.00	0.91
-0.80	0.07	27.24	0.00	0.00	0.00	0.00	0.83
-0.70	0.06	27.21	0.00	0.00	0.00	0.00	0.75
-0.60	0.05	27.18	0.00	0.00	0.00	0.00	0.70
-0.50	0.05	27.14	0.00	0.00	0.00	0.00	0.65
-0.40	0.05	27.12	0.00	0.00	0.00	0.00	0.59
-0.30	0.04	27.09	0.00	0.00	0.00	0.00	0.56
-0.20	0.04	27.05	0.00	0.00	0.00	0.00	0.54
-0.10	0.04	27.03	0.00	0.00	0.00	0.00	0.52
0.00	0.04	26.99	0.00	0.00	0.00	0.00	0.51
0.10	0.04	26.96	0.00	0.00	0.00	0.00	0.53
0.20	0.05	26.93	0.00	0.00	0.00	0.00	0.56
0.30	0.05	26.89	0.00	0.00	0.00	0.00	0.59
0.40	0.06	26.86	0.00	0.00	0.00	0.00	0.65
0.50	0.07	26.83	0.00	0.00	0.00	0.00	0.70
0.60	0.08	26.80	0.00	0.00	0.00	0.00	0.77
0.70	0.09	26.77	0.00	0.00	0.00	0.00	0.86
0.80	0.11	26.74	0.00	0.00	0.00	0.04	0.95
0.90	0.12	26.71	0.00	0.00	0.00	0.09	1.00
1.00	0.14	26.68	0.00	0.00	0.00	0.13	1.00
1.10	0.15	26.64	0.00	0.00	0.00	0.18	1.00
1.20	0.17	26.62	0.00	0.00	0.00	0.22	1.00
1.30	0.19	26.58	0.00	0.00	0.00	0.27	1.00
1.40	0.21	26.55	0.00	0.00	0.00	0.33	1.00
1.50	0.22	26.52	0.00	0.00	0.00	0.38	1.00
1.60	0.24	26.49	0.00	0.00	0.00	0.43	1.00
1.70	0.26	26.46	0.00	0.00	0.00	0.49	1.00
1.80	0.27	26.43	0.00	0.00	0.00	0.54	1.00
1.90	0.29	26.40	0.00	0.00	0.00	0.59	1.00
2.00	0.30	26.37	0.00	0.00	0.00	0.65	1.00

Appendix L: September Pricing

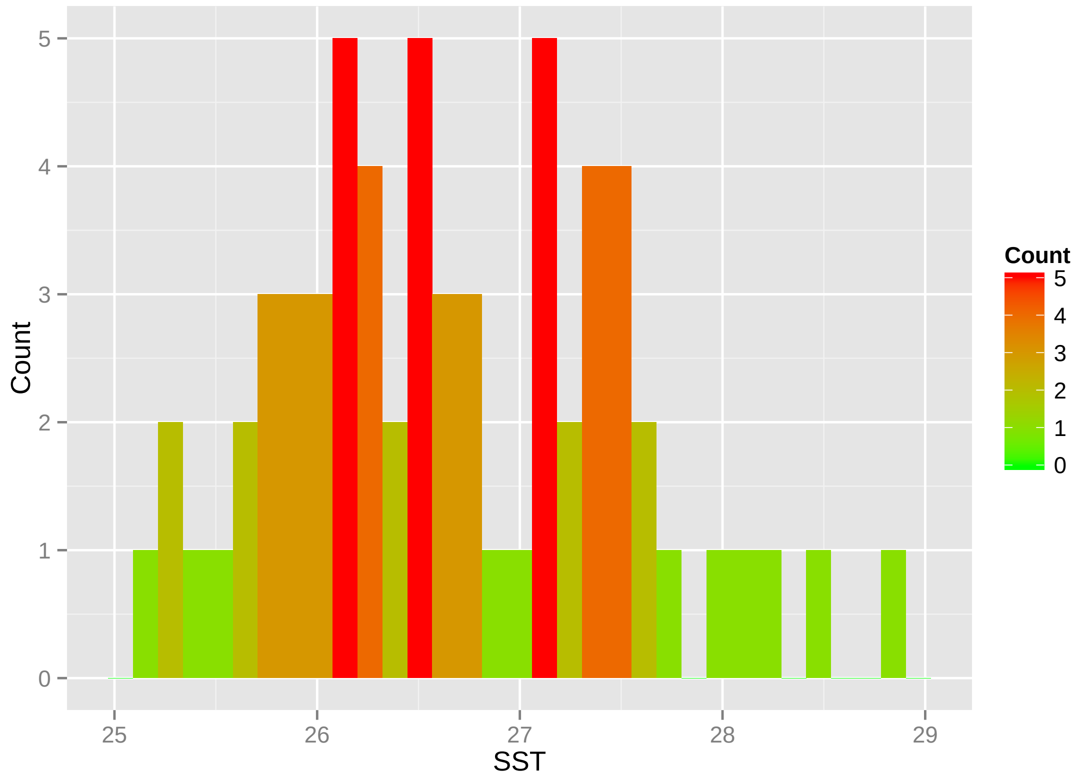


Figure 87: Histogram of September SST for Niño 3.4 ERSST.3b

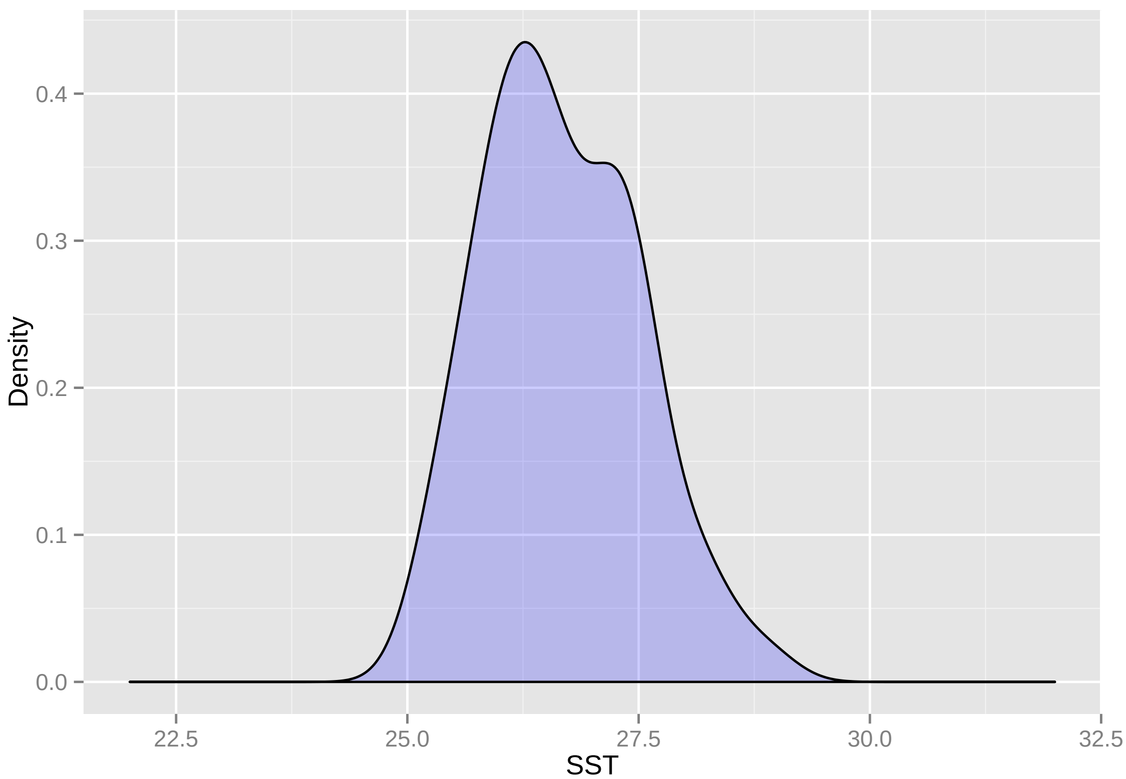


Figure 88: Kernel density estimate of September SST for Niño 3.4 ERSST.3b

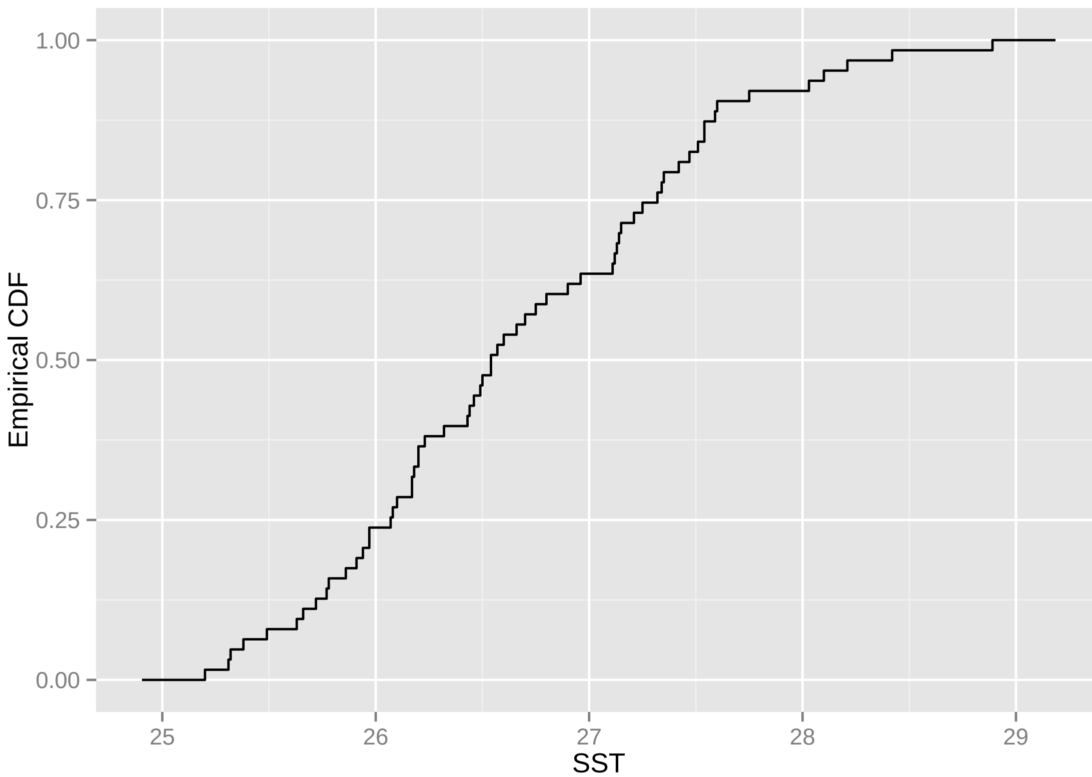


Figure 89: ECDF of September SST for Niño 3.4 ERSST.3b

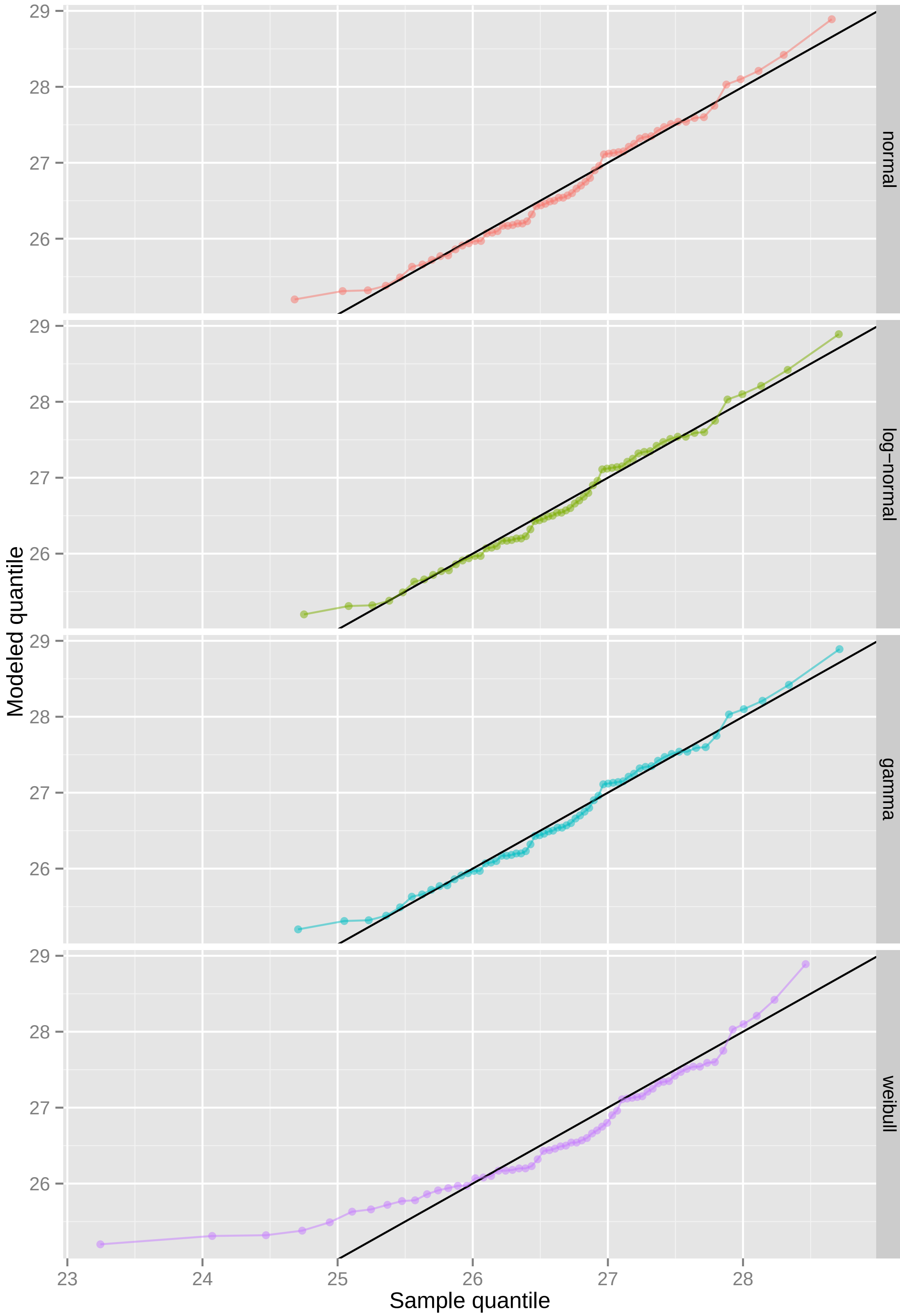


Figure 90: QQ plots of September SST for Niño 3.4 ERSST.3b compared to samples from various distributions (n=2 million)

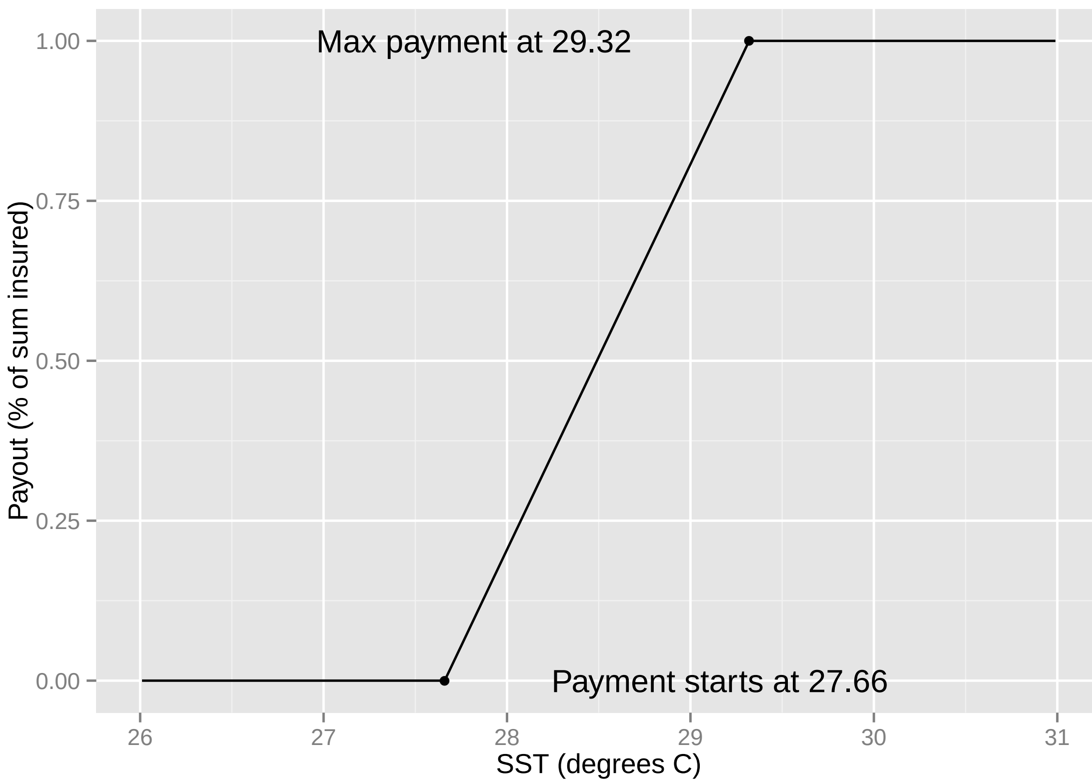


Figure 91: Payout function for call option on September SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations above the baseline

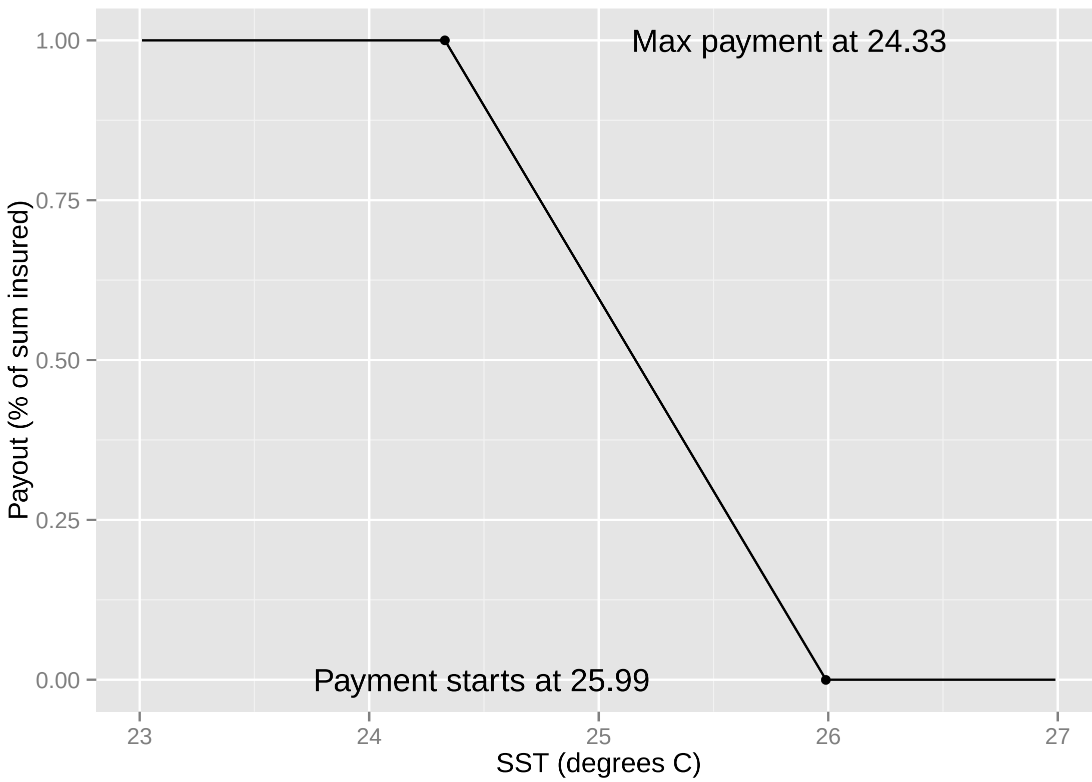


Figure 92: Payout function for put option on September SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

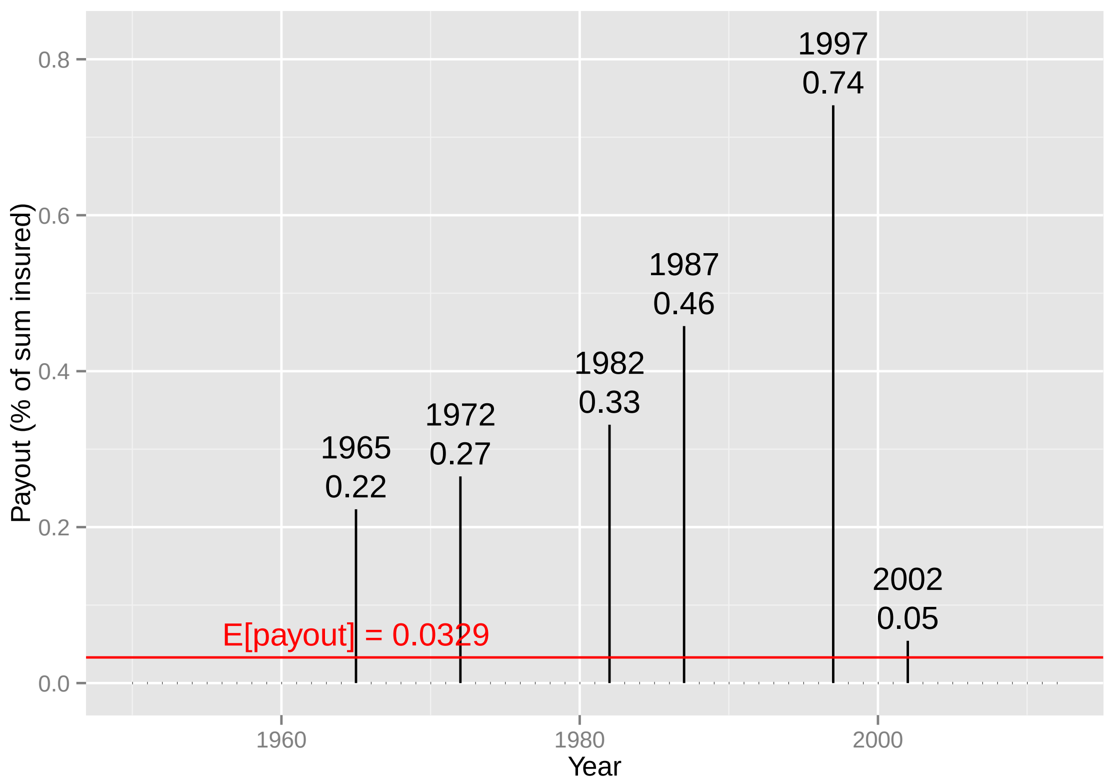


Figure 93: Historical burn on call option for September SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations above the baseline

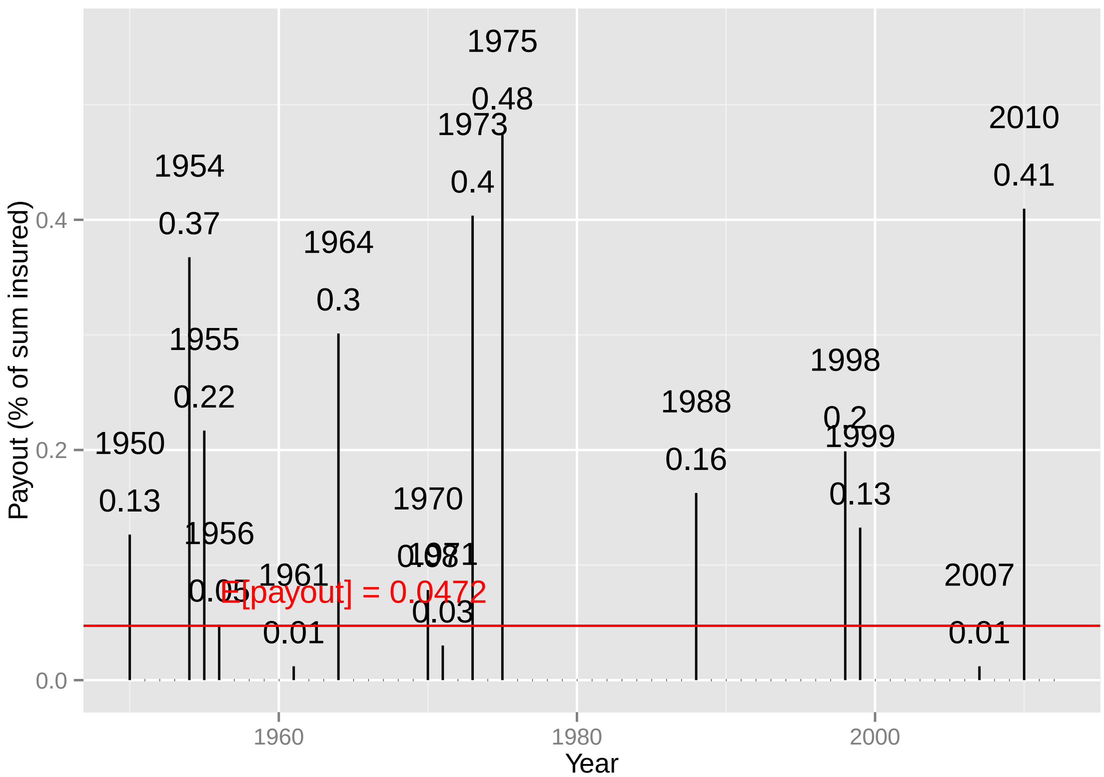


Figure 94: Historical burn on put option on September SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

Table 159: Bayesian regression linking September Niño 3.4 SST anomalies to average of relevant IRI ensemble forecasts

	mean	sd	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q	n_eff	Rhat
July forecast average covering September Niño 3.4 SST anomalies									
α	-0.10	0.10	-0.40	-0.20	-0.10	0.00	0.20	94715	1
β	1.10	0.20	0.70	1.00	1.10	1.30	1.60	93621	1
σ_y^2	0.20	0.10	0.10	0.10	0.20	0.20	0.50	57820	1
June forecast average covering September Niño 3.4 SST anomalies									
α	0.00	0.10	-0.30	-0.10	0.00	0.00	0.20	96199	1
β	1.40	0.30	0.80	1.20	1.40	1.60	2.00	95660	1
σ_y^2	0.20	0.10	0.10	0.10	0.20	0.30	0.60	58265	1
May forecast average covering September Niño 3.4 SST anomalies									
α	-0.10	0.20	-0.50	-0.20	-0.10	0.00	0.30	91279	1
β	1.50	0.50	0.50	1.20	1.50	1.80	2.50	93276	1
σ_y^2	0.40	0.20	0.10	0.20	0.30	0.50	1.00	58512	1
April forecast average covering September Niño 3.4 SST anomalies									
α	-0.10	0.20	-0.50	-0.20	-0.10	0.00	0.20	90804	1
β	1.80	0.50	0.80	1.50	1.80	2.10	2.80	89824	1
σ_y^2	0.30	0.20	0.10	0.20	0.30	0.40	0.80	59601	1
March forecast average covering September Niño 3.4 SST anomalies									
α	0.00	0.20	-0.40	-0.20	0.00	0.10	0.40	101815	1
β	1.60	0.80	0.00	1.10	1.60	2.10	3.20	96553	1
σ_y^2	0.60	0.30	0.20	0.30	0.50	0.70	1.40	59817	1
February forecast average covering September Niño 3.4 SST anomalies									
α	-0.10	0.30	-0.70	-0.30	-0.10	0.10	0.50	98911	1
β	0.70	1.20	-1.70	0.00	0.70	1.50	3.10	88134	1
σ_y^2	0.90	0.70	0.30	0.50	0.70	1.10	2.70	55087	1
January forecast average covering September Niño 3.4 SST anomalies									
α	0.00	0.30	-0.60	-0.20	0.00	0.10	0.50	97041	1
β	0.60	1.40	-2.20	-0.20	0.60	1.50	3.40	90519	1
σ_y^2	0.90	0.60	0.30	0.50	0.70	1.00	2.30	57789	1
December forecast average covering September Niño 3.4 SST anomalies									
α	0.00	0.30	-0.60	-0.20	0.00	0.20	0.60	86022	1
β	-0.30	1.50	-3.20	-1.20	-0.30	0.60	2.60	84927	1
σ_y^2	0.90	0.60	0.30	0.50	0.70	1.00	2.40	58687	1
November forecast average covering September Niño 3.4 SST anomalies									
α	0.10	0.40	-0.60	-0.10	0.10	0.30	0.80	61600	1
β	-0.60	1.50	-3.50	-1.50	-0.60	0.30	2.30	60511	1
σ_y^2	0.90	0.60	0.30	0.50	0.70	1.00	2.30	53764	1

Table 160: Call option prices for September Nino 3.4 SST conditioned on IRI ensemble forecasts released in July

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	24.47	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	24.59	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.70	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.81	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.92	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	25.03	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	25.14	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	25.26	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	25.37	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.48	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.59	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.70	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.81	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.92	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	26.04	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	26.15	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.26	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.37	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.48	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	26.59	0.00	0.00	0.00	0.00	0.00
0.00	0.00	26.70	0.00	0.00	0.00	0.00	0.00
0.10	0.01	26.82	0.00	0.00	0.00	0.00	0.05
0.20	0.01	26.93	0.00	0.00	0.00	0.00	0.10
0.30	0.01	27.04	0.00	0.00	0.00	0.00	0.18
0.40	0.02	27.15	0.00	0.00	0.00	0.00	0.24
0.50	0.03	27.26	0.00	0.00	0.00	0.00	0.32
0.60	0.04	27.37	0.00	0.00	0.00	0.00	0.38
0.70	0.06	27.48	0.00	0.00	0.00	0.07	0.46
0.80	0.09	27.59	0.00	0.00	0.00	0.14	0.54
0.90	0.13	27.71	0.00	0.00	0.03	0.21	0.61
1.00	0.17	27.82	0.00	0.00	0.10	0.28	0.68
1.10	0.21	27.93	0.00	0.00	0.16	0.35	0.77
1.20	0.27	28.04	0.00	0.04	0.23	0.42	0.84
1.30	0.32	28.16	0.00	0.10	0.30	0.49	0.94
1.40	0.38	28.26	0.00	0.16	0.36	0.56	1.00
1.50	0.44	28.37	0.00	0.23	0.43	0.63	1.00
1.60	0.50	28.49	0.00	0.29	0.50	0.71	1.00
1.70	0.56	28.60	0.00	0.35	0.56	0.78	1.00
1.80	0.61	28.71	0.00	0.41	0.63	0.85	1.00
1.90	0.66	28.82	0.00	0.47	0.70	0.92	1.00
2.00	0.71	28.93	0.02	0.54	0.76	1.00	1.00

Table 161: Call option prices for September Nino 3.4 SST conditioned on IRI ensemble forecasts released in June

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	24.04	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	24.18	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.31	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.46	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.59	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.73	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	24.86	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	25.00	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	25.14	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.27	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.41	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.55	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.69	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.82	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.96	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	26.09	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.23	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.36	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.50	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	26.64	0.00	0.00	0.00	0.00	0.00
0.00	0.01	26.78	0.00	0.00	0.00	0.00	0.06
0.10	0.01	26.91	0.00	0.00	0.00	0.00	0.14
0.20	0.02	27.05	0.00	0.00	0.00	0.00	0.23
0.30	0.03	27.18	0.00	0.00	0.00	0.00	0.31
0.40	0.04	27.32	0.00	0.00	0.00	0.00	0.39
0.50	0.07	27.46	0.00	0.00	0.00	0.07	0.48
0.60	0.10	27.59	0.00	0.00	0.00	0.15	0.58
0.70	0.14	27.73	0.00	0.00	0.04	0.24	0.67
0.80	0.20	27.87	0.00	0.00	0.12	0.32	0.77
0.90	0.26	28.01	0.00	0.00	0.21	0.42	0.86
1.00	0.32	28.14	0.00	0.08	0.29	0.50	0.96
1.10	0.39	28.28	0.00	0.16	0.37	0.59	1.00
1.20	0.46	28.41	0.00	0.23	0.45	0.68	1.00
1.30	0.53	28.55	0.00	0.31	0.54	0.77	1.00
1.40	0.60	28.69	0.00	0.39	0.62	0.85	1.00
1.50	0.66	28.83	0.00	0.46	0.70	0.94	1.00
1.60	0.72	28.96	0.00	0.53	0.78	1.00	1.00
1.70	0.77	29.10	0.05	0.61	0.87	1.00	1.00
1.80	0.81	29.24	0.10	0.68	0.95	1.00	1.00
1.90	0.85	29.38	0.16	0.76	1.00	1.00	1.00
2.00	0.88	29.51	0.21	0.83	1.00	1.00	1.00

Table 162: Call option prices for September Nino 3.4 SST conditioned on IRI ensemble forecasts released in May

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	23.74	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	23.89	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.04	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.19	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.34	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.49	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	24.64	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	24.79	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	24.94	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.09	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.24	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.39	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.53	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.68	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.84	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	25.98	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.14	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.28	0.00	0.00	0.00	0.00	0.00
-0.20	0.01	26.43	0.00	0.00	0.00	0.00	0.06
-0.10	0.01	26.58	0.00	0.00	0.00	0.00	0.13
0.00	0.01	26.73	0.00	0.00	0.00	0.00	0.21
0.10	0.02	26.88	0.00	0.00	0.00	0.00	0.31
0.20	0.03	27.03	0.00	0.00	0.00	0.00	0.40
0.30	0.05	27.18	0.00	0.00	0.00	0.00	0.49
0.40	0.07	27.33	0.00	0.00	0.00	0.04	0.60
0.50	0.10	27.47	0.00	0.00	0.00	0.14	0.69
0.60	0.15	27.62	0.00	0.00	0.00	0.23	0.80
0.70	0.20	27.77	0.00	0.00	0.07	0.33	0.91
0.80	0.25	27.92	0.00	0.00	0.16	0.43	1.00
0.90	0.31	28.07	0.00	0.00	0.25	0.53	1.00
1.00	0.38	28.21	0.00	0.04	0.33	0.62	1.00
1.10	0.45	28.37	0.00	0.13	0.43	0.73	1.00
1.20	0.51	28.52	0.00	0.20	0.52	0.82	1.00
1.30	0.57	28.66	0.00	0.28	0.60	0.93	1.00
1.40	0.63	28.82	0.00	0.36	0.70	1.00	1.00
1.50	0.68	28.97	0.00	0.44	0.78	1.00	1.00
1.60	0.73	29.12	0.00	0.51	0.88	1.00	1.00
1.70	0.77	29.26	0.00	0.59	0.96	1.00	1.00
1.80	0.80	29.42	0.00	0.67	1.00	1.00	1.00
1.90	0.83	29.57	0.00	0.74	1.00	1.00	1.00
2.00	0.85	29.71	0.00	0.82	1.00	1.00	1.00

Table 163: Call option prices for September Nino 3.4 SST conditioned on IRI ensemble forecasts released in April

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	23.10	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	23.28	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	23.46	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	23.64	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	23.82	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.00	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	24.18	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	24.36	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	24.54	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	24.71	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	24.90	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.08	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.26	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.44	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.62	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	25.80	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	25.98	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.16	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.34	0.00	0.00	0.00	0.00	0.00
-0.10	0.01	26.51	0.00	0.00	0.00	0.00	0.03
0.00	0.01	26.70	0.00	0.00	0.00	0.00	0.14
0.10	0.02	26.88	0.00	0.00	0.00	0.00	0.23
0.20	0.03	27.06	0.00	0.00	0.00	0.00	0.35
0.30	0.05	27.24	0.00	0.00	0.00	0.00	0.47
0.40	0.08	27.42	0.00	0.00	0.00	0.08	0.59
0.50	0.13	27.60	0.00	0.00	0.00	0.20	0.72
0.60	0.19	27.78	0.00	0.00	0.07	0.31	0.85
0.70	0.26	27.97	0.00	0.00	0.18	0.43	0.98
0.80	0.34	28.14	0.00	0.04	0.29	0.55	1.00
0.90	0.42	28.32	0.00	0.13	0.40	0.67	1.00
1.00	0.51	28.51	0.00	0.23	0.51	0.79	1.00
1.10	0.58	28.68	0.00	0.32	0.61	0.91	1.00
1.20	0.66	28.87	0.00	0.42	0.72	1.00	1.00
1.30	0.72	29.04	0.00	0.51	0.83	1.00	1.00
1.40	0.77	29.22	0.00	0.61	0.94	1.00	1.00
1.50	0.82	29.40	0.00	0.71	1.00	1.00	1.00
1.60	0.85	29.58	0.00	0.80	1.00	1.00	1.00
1.70	0.88	29.77	0.06	0.89	1.00	1.00	1.00
1.80	0.90	29.94	0.13	0.99	1.00	1.00	1.00
1.90	0.92	30.12	0.18	1.00	1.00	1.00	1.00
2.00	0.93	30.30	0.24	1.00	1.00	1.00	1.00

Table 164: Call option prices for September Nino 3.4 SST conditioned on IRI ensemble forecasts released in March

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.01	23.61	0.00	0.00	0.00	0.00	0.00
-1.90	0.01	23.78	0.00	0.00	0.00	0.00	0.00
-1.80	0.01	23.93	0.00	0.00	0.00	0.00	0.00
-1.70	0.01	24.10	0.00	0.00	0.00	0.00	0.00
-1.60	0.01	24.26	0.00	0.00	0.00	0.00	0.00
-1.50	0.01	24.41	0.00	0.00	0.00	0.00	0.00
-1.40	0.01	24.57	0.00	0.00	0.00	0.00	0.00
-1.30	0.01	24.73	0.00	0.00	0.00	0.00	0.00
-1.20	0.01	24.89	0.00	0.00	0.00	0.00	0.00
-1.10	0.01	25.05	0.00	0.00	0.00	0.00	0.00
-1.00	0.01	25.21	0.00	0.00	0.00	0.00	0.00
-0.90	0.01	25.37	0.00	0.00	0.00	0.00	0.00
-0.80	0.01	25.52	0.00	0.00	0.00	0.00	0.00
-0.70	0.01	25.68	0.00	0.00	0.00	0.00	0.00
-0.60	0.01	25.84	0.00	0.00	0.00	0.00	0.03
-0.50	0.01	26.01	0.00	0.00	0.00	0.00	0.10
-0.40	0.01	26.16	0.00	0.00	0.00	0.00	0.14
-0.30	0.01	26.33	0.00	0.00	0.00	0.00	0.20
-0.20	0.02	26.48	0.00	0.00	0.00	0.00	0.26
-0.10	0.02	26.65	0.00	0.00	0.00	0.00	0.34
0.00	0.03	26.80	0.00	0.00	0.00	0.00	0.42
0.10	0.05	26.96	0.00	0.00	0.00	0.00	0.51
0.20	0.07	27.12	0.00	0.00	0.00	0.00	0.63
0.30	0.09	27.28	0.00	0.00	0.00	0.07	0.74
0.40	0.13	27.44	0.00	0.00	0.00	0.18	0.87
0.50	0.18	27.61	0.00	0.00	0.00	0.29	1.00
0.60	0.23	27.76	0.00	0.00	0.06	0.39	1.00
0.70	0.29	27.92	0.00	0.00	0.16	0.51	1.00
0.80	0.35	28.08	0.00	0.00	0.25	0.62	1.00
0.90	0.41	28.24	0.00	0.00	0.35	0.74	1.00
1.00	0.47	28.40	0.00	0.03	0.45	0.86	1.00
1.10	0.52	28.55	0.00	0.11	0.54	0.96	1.00
1.20	0.57	28.71	0.00	0.19	0.63	1.00	1.00
1.30	0.62	28.88	0.00	0.26	0.73	1.00	1.00
1.40	0.66	29.04	0.00	0.34	0.83	1.00	1.00
1.50	0.69	29.19	0.00	0.40	0.92	1.00	1.00
1.60	0.73	29.35	0.00	0.47	1.00	1.00	1.00
1.70	0.75	29.52	0.00	0.55	1.00	1.00	1.00
1.80	0.78	29.68	0.00	0.62	1.00	1.00	1.00
1.90	0.80	29.84	0.00	0.69	1.00	1.00	1.00
2.00	0.81	29.99	0.00	0.75	1.00	1.00	1.00

Table 165: Call option prices for September Nino 3.4 SST conditioned on IRI ensemble forecasts released in February

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.10	25.27	0.00	0.00	0.00	0.00	1.00
-1.90	0.10	25.34	0.00	0.00	0.00	0.00	1.00
-1.80	0.10	25.42	0.00	0.00	0.00	0.00	1.00
-1.70	0.09	25.48	0.00	0.00	0.00	0.00	1.00
-1.60	0.09	25.56	0.00	0.00	0.00	0.00	1.00
-1.50	0.08	25.64	0.00	0.00	0.00	0.00	1.00
-1.40	0.08	25.70	0.00	0.00	0.00	0.00	1.00
-1.30	0.08	25.78	0.00	0.00	0.00	0.00	1.00
-1.20	0.07	25.86	0.00	0.00	0.00	0.00	1.00
-1.10	0.07	25.92	0.00	0.00	0.00	0.00	1.00
-1.00	0.06	26.00	0.00	0.00	0.00	0.00	0.94
-0.90	0.06	26.08	0.00	0.00	0.00	0.00	0.89
-0.80	0.06	26.15	0.00	0.00	0.00	0.00	0.83
-0.70	0.05	26.22	0.00	0.00	0.00	0.00	0.76
-0.60	0.05	26.31	0.00	0.00	0.00	0.00	0.71
-0.50	0.05	26.38	0.00	0.00	0.00	0.00	0.68
-0.40	0.05	26.44	0.00	0.00	0.00	0.00	0.65
-0.30	0.05	26.52	0.00	0.00	0.00	0.00	0.63
-0.20	0.05	26.59	0.00	0.00	0.00	0.00	0.63
-0.10	0.05	26.66	0.00	0.00	0.00	0.00	0.62
0.00	0.05	26.73	0.00	0.00	0.00	0.00	0.65
0.10	0.06	26.82	0.00	0.00	0.00	0.00	0.73
0.20	0.07	26.88	0.00	0.00	0.00	0.00	0.77
0.30	0.08	26.96	0.00	0.00	0.00	0.00	0.85
0.40	0.10	27.02	0.00	0.00	0.00	0.02	0.94
0.50	0.12	27.11	0.00	0.00	0.00	0.08	1.00
0.60	0.14	27.18	0.00	0.00	0.00	0.15	1.00
0.70	0.17	27.25	0.00	0.00	0.00	0.22	1.00
0.80	0.19	27.33	0.00	0.00	0.00	0.29	1.00
0.90	0.22	27.40	0.00	0.00	0.00	0.36	1.00
1.00	0.25	27.48	0.00	0.00	0.00	0.45	1.00
1.10	0.27	27.54	0.00	0.00	0.00	0.52	1.00
1.20	0.29	27.62	0.00	0.00	0.00	0.59	1.00
1.30	0.32	27.69	0.00	0.00	0.01	0.68	1.00
1.40	0.34	27.77	0.00	0.00	0.07	0.76	1.00
1.50	0.36	27.83	0.00	0.00	0.11	0.84	1.00
1.60	0.38	27.92	0.00	0.00	0.15	0.92	1.00
1.70	0.40	27.99	0.00	0.00	0.19	1.00	1.00
1.80	0.42	28.06	0.00	0.00	0.24	1.00	1.00
1.90	0.44	28.13	0.00	0.00	0.29	1.00	1.00
2.00	0.45	28.21	0.00	0.00	0.33	1.00	1.00

Table 166: Call option prices for September Nino 3.4 SST conditioned on IRI ensemble forecasts released in January

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.15	25.55	0.00	0.00	0.00	0.00	1.00
-1.90	0.14	25.61	0.00	0.00	0.00	0.00	1.00
-1.80	0.14	25.67	0.00	0.00	0.00	0.00	1.00
-1.70	0.13	25.74	0.00	0.00	0.00	0.00	1.00
-1.60	0.13	25.79	0.00	0.00	0.00	0.00	1.00
-1.50	0.12	25.86	0.00	0.00	0.00	0.00	1.00
-1.40	0.12	25.92	0.00	0.00	0.00	0.00	1.00
-1.30	0.11	25.98	0.00	0.00	0.00	0.00	1.00
-1.20	0.10	26.05	0.00	0.00	0.00	0.00	1.00
-1.10	0.10	26.10	0.00	0.00	0.00	0.00	1.00
-1.00	0.09	26.17	0.00	0.00	0.00	0.00	1.00
-0.90	0.08	26.23	0.00	0.00	0.00	0.00	1.00
-0.80	0.08	26.28	0.00	0.00	0.00	0.00	1.00
-0.70	0.07	26.36	0.00	0.00	0.00	0.00	0.93
-0.60	0.07	26.43	0.00	0.00	0.00	0.00	0.87
-0.50	0.06	26.48	0.00	0.00	0.00	0.00	0.76
-0.40	0.05	26.54	0.00	0.00	0.00	0.00	0.72
-0.30	0.05	26.60	0.00	0.00	0.00	0.00	0.66
-0.20	0.05	26.66	0.00	0.00	0.00	0.00	0.64
-0.10	0.05	26.73	0.00	0.00	0.00	0.00	0.62
0.00	0.06	26.80	0.00	0.00	0.00	0.00	0.66
0.10	0.06	26.85	0.00	0.00	0.00	0.00	0.67
0.20	0.07	26.91	0.00	0.00	0.00	0.00	0.74
0.30	0.08	26.97	0.00	0.00	0.00	0.00	0.81
0.40	0.10	27.04	0.00	0.00	0.00	0.02	0.94
0.50	0.12	27.10	0.00	0.00	0.00	0.08	1.00
0.60	0.14	27.16	0.00	0.00	0.00	0.15	1.00
0.70	0.17	27.22	0.00	0.00	0.00	0.23	1.00
0.80	0.20	27.29	0.00	0.00	0.00	0.30	1.00
0.90	0.22	27.35	0.00	0.00	0.00	0.37	1.00
1.00	0.25	27.40	0.00	0.00	0.00	0.45	1.00
1.10	0.27	27.47	0.00	0.00	0.00	0.54	1.00
1.20	0.30	27.54	0.00	0.00	0.00	0.62	1.00
1.30	0.32	27.60	0.00	0.00	0.00	0.70	1.00
1.40	0.34	27.66	0.00	0.00	0.01	0.78	1.00
1.50	0.36	27.73	0.00	0.00	0.05	0.87	1.00
1.60	0.38	27.78	0.00	0.00	0.08	0.95	1.00
1.70	0.39	27.85	0.00	0.00	0.12	1.00	1.00
1.80	0.41	27.91	0.00	0.00	0.16	1.00	1.00
1.90	0.42	27.97	0.00	0.00	0.20	1.00	1.00
2.00	0.43	28.03	0.00	0.00	0.23	1.00	1.00

Table 167: Call option prices for September Nino 3.4 SST conditioned on IRI ensemble forecasts released in December

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.36	27.40	0.00	0.00	0.00	1.00	1.00
-1.90	0.35	27.37	0.00	0.00	0.00	0.98	1.00
-1.80	0.34	27.34	0.00	0.00	0.00	0.90	1.00
-1.70	0.33	27.32	0.00	0.00	0.00	0.84	1.00
-1.60	0.32	27.29	0.00	0.00	0.00	0.78	1.00
-1.50	0.30	27.26	0.00	0.00	0.00	0.70	1.00
-1.40	0.29	27.23	0.00	0.00	0.00	0.64	1.00
-1.30	0.27	27.20	0.00	0.00	0.00	0.57	1.00
-1.20	0.26	27.18	0.00	0.00	0.00	0.49	1.00
-1.10	0.24	27.15	0.00	0.00	0.00	0.43	1.00
-1.00	0.22	27.12	0.00	0.00	0.00	0.37	1.00
-0.90	0.20	27.09	0.00	0.00	0.00	0.31	1.00
-0.80	0.19	27.07	0.00	0.00	0.00	0.25	1.00
-0.70	0.17	27.04	0.00	0.00	0.00	0.19	1.00
-0.60	0.15	27.00	0.00	0.00	0.00	0.14	1.00
-0.50	0.13	26.98	0.00	0.00	0.00	0.08	1.00
-0.40	0.11	26.96	0.00	0.00	0.00	0.03	1.00
-0.30	0.09	26.93	0.00	0.00	0.00	0.00	0.93
-0.20	0.08	26.90	0.00	0.00	0.00	0.00	0.83
-0.10	0.07	26.87	0.00	0.00	0.00	0.00	0.76
0.00	0.06	26.84	0.00	0.00	0.00	0.00	0.69
0.10	0.06	26.81	0.00	0.00	0.00	0.00	0.66
0.20	0.06	26.79	0.00	0.00	0.00	0.00	0.67
0.30	0.06	26.77	0.00	0.00	0.00	0.00	0.71
0.40	0.06	26.74	0.00	0.00	0.00	0.00	0.74
0.50	0.07	26.71	0.00	0.00	0.00	0.00	0.79
0.60	0.08	26.68	0.00	0.00	0.00	0.00	0.88
0.70	0.09	26.66	0.00	0.00	0.00	0.00	0.98
0.80	0.10	26.62	0.00	0.00	0.00	0.00	1.00
0.90	0.11	26.60	0.00	0.00	0.00	0.00	1.00
1.00	0.12	26.57	0.00	0.00	0.00	0.00	1.00
1.10	0.13	26.54	0.00	0.00	0.00	0.00	1.00
1.20	0.14	26.52	0.00	0.00	0.00	0.01	1.00
1.30	0.15	26.48	0.00	0.00	0.00	0.04	1.00
1.40	0.16	26.46	0.00	0.00	0.00	0.07	1.00
1.50	0.17	26.43	0.00	0.00	0.00	0.10	1.00
1.60	0.18	26.41	0.00	0.00	0.00	0.14	1.00
1.70	0.19	26.37	0.00	0.00	0.00	0.17	1.00
1.80	0.20	26.36	0.00	0.00	0.00	0.21	1.00
1.90	0.21	26.32	0.00	0.00	0.00	0.23	1.00
2.00	0.21	26.29	0.00	0.00	0.00	0.27	1.00

Table 168: Call option prices for September Nino 3.4 SST conditioned on IRI ensemble forecasts released in November

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.46	28.18	0.00	0.00	0.31	1.00	1.00
-1.90	0.45	28.11	0.00	0.00	0.28	1.00	1.00
-1.80	0.44	28.05	0.00	0.00	0.23	1.00	1.00
-1.70	0.43	27.99	0.00	0.00	0.20	1.00	1.00
-1.60	0.41	27.92	0.00	0.00	0.16	1.00	1.00
-1.50	0.40	27.86	0.00	0.00	0.12	1.00	1.00
-1.40	0.38	27.80	0.00	0.00	0.08	1.00	1.00
-1.30	0.37	27.74	0.00	0.00	0.04	0.93	1.00
-1.20	0.35	27.68	0.00	0.00	0.01	0.85	1.00
-1.10	0.33	27.61	0.00	0.00	0.00	0.75	1.00
-1.00	0.31	27.55	0.00	0.00	0.00	0.67	1.00
-0.90	0.29	27.49	0.00	0.00	0.00	0.59	1.00
-0.80	0.26	27.42	0.00	0.00	0.00	0.50	1.00
-0.70	0.24	27.37	0.00	0.00	0.00	0.42	1.00
-0.60	0.21	27.30	0.00	0.00	0.00	0.34	1.00
-0.50	0.18	27.24	0.00	0.00	0.00	0.26	1.00
-0.40	0.15	27.16	0.00	0.00	0.00	0.18	1.00
-0.30	0.13	27.11	0.00	0.00	0.00	0.11	1.00
-0.20	0.11	27.05	0.00	0.00	0.00	0.04	0.95
-0.10	0.09	26.98	0.00	0.00	0.00	0.00	0.84
0.00	0.07	26.92	0.00	0.00	0.00	0.00	0.73
0.10	0.06	26.86	0.00	0.00	0.00	0.00	0.68
0.20	0.06	26.80	0.00	0.00	0.00	0.00	0.66
0.30	0.05	26.74	0.00	0.00	0.00	0.00	0.62
0.40	0.05	26.68	0.00	0.00	0.00	0.00	0.64
0.50	0.05	26.60	0.00	0.00	0.00	0.00	0.67
0.60	0.06	26.55	0.00	0.00	0.00	0.00	0.72
0.70	0.06	26.48	0.00	0.00	0.00	0.00	0.77
0.80	0.07	26.42	0.00	0.00	0.00	0.00	0.86
0.90	0.07	26.36	0.00	0.00	0.00	0.00	0.96
1.00	0.08	26.29	0.00	0.00	0.00	0.00	1.00
1.10	0.09	26.23	0.00	0.00	0.00	0.00	1.00
1.20	0.10	26.16	0.00	0.00	0.00	0.00	1.00
1.30	0.10	26.11	0.00	0.00	0.00	0.00	1.00
1.40	0.11	26.04	0.00	0.00	0.00	0.00	1.00
1.50	0.12	25.98	0.00	0.00	0.00	0.00	1.00
1.60	0.12	25.92	0.00	0.00	0.00	0.00	1.00
1.70	0.13	25.85	0.00	0.00	0.00	0.00	1.00
1.80	0.14	25.79	0.00	0.00	0.00	0.00	1.00
1.90	0.14	25.73	0.00	0.00	0.00	0.00	1.00
2.00	0.15	25.67	0.00	0.00	0.00	0.00	1.00

Table 169: Put option prices for September Nino 3.4 SST conditioned on IRI ensemble forecasts released in July

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.80	24.47	0.12	0.67	0.92	1.00	1.00
-1.90	0.77	24.59	0.07	0.61	0.85	1.00	1.00
-1.80	0.72	24.70	0.03	0.55	0.78	1.00	1.00
-1.70	0.67	24.81	0.00	0.48	0.71	0.94	1.00
-1.60	0.62	24.92	0.00	0.43	0.65	0.87	1.00
-1.50	0.57	25.03	0.00	0.36	0.58	0.79	1.00
-1.40	0.51	25.14	0.00	0.30	0.51	0.72	1.00
-1.30	0.45	25.26	0.00	0.24	0.44	0.65	1.00
-1.20	0.39	25.37	0.00	0.18	0.37	0.57	1.00
-1.10	0.33	25.48	0.00	0.11	0.31	0.50	0.94
-1.00	0.28	25.59	0.00	0.05	0.24	0.43	0.86
-0.90	0.23	25.70	0.00	0.00	0.18	0.36	0.78
-0.80	0.18	25.81	0.00	0.00	0.11	0.29	0.71
-0.70	0.13	25.92	0.00	0.00	0.04	0.22	0.62
-0.60	0.10	26.04	0.00	0.00	0.00	0.15	0.55
-0.50	0.07	26.15	0.00	0.00	0.00	0.08	0.47
-0.40	0.05	26.26	0.00	0.00	0.00	0.01	0.40
-0.30	0.03	26.37	0.00	0.00	0.00	0.00	0.32
-0.20	0.02	26.48	0.00	0.00	0.00	0.00	0.25
-0.10	0.01	26.59	0.00	0.00	0.00	0.00	0.19
0.00	0.01	26.70	0.00	0.00	0.00	0.00	0.12
0.10	0.01	26.82	0.00	0.00	0.00	0.00	0.05
0.20	0.00	26.93	0.00	0.00	0.00	0.00	0.00
0.30	0.00	27.04	0.00	0.00	0.00	0.00	0.00
0.40	0.00	27.15	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.26	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.37	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.48	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.59	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.71	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.82	0.00	0.00	0.00	0.00	0.00
1.10	0.00	27.93	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.04	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.16	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.26	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.37	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.49	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.60	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.71	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.82	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.93	0.00	0.00	0.00	0.00	0.00

Table 170: Put option prices for September Nino 3.4 SST conditioned on IRI ensemble forecasts released in June

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.89	24.04	0.22	0.87	1.00	1.00	1.00
-1.90	0.87	24.18	0.16	0.80	1.00	1.00	1.00
-1.80	0.83	24.31	0.11	0.73	1.00	1.00	1.00
-1.70	0.80	24.46	0.06	0.65	0.93	1.00	1.00
-1.60	0.75	24.59	0.00	0.58	0.85	1.00	1.00
-1.50	0.70	24.73	0.00	0.50	0.76	1.00	1.00
-1.40	0.64	24.86	0.00	0.43	0.68	0.93	1.00
-1.30	0.58	25.00	0.00	0.35	0.60	0.83	1.00
-1.20	0.51	25.14	0.00	0.28	0.51	0.75	1.00
-1.10	0.44	25.27	0.00	0.21	0.43	0.66	1.00
-1.00	0.37	25.41	0.00	0.13	0.35	0.57	1.00
-0.90	0.31	25.55	0.00	0.05	0.27	0.48	0.96
-0.80	0.24	25.69	0.00	0.00	0.18	0.39	0.85
-0.70	0.18	25.82	0.00	0.00	0.10	0.31	0.74
-0.60	0.13	25.96	0.00	0.00	0.02	0.22	0.66
-0.50	0.09	26.09	0.00	0.00	0.00	0.13	0.56
-0.40	0.06	26.23	0.00	0.00	0.00	0.05	0.48
-0.30	0.04	26.36	0.00	0.00	0.00	0.00	0.39
-0.20	0.02	26.50	0.00	0.00	0.00	0.00	0.29
-0.10	0.01	26.64	0.00	0.00	0.00	0.00	0.20
0.00	0.01	26.78	0.00	0.00	0.00	0.00	0.12
0.10	0.01	26.91	0.00	0.00	0.00	0.00	0.04
0.20	0.00	27.05	0.00	0.00	0.00	0.00	0.00
0.30	0.00	27.18	0.00	0.00	0.00	0.00	0.00
0.40	0.00	27.32	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.46	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.59	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.73	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.87	0.00	0.00	0.00	0.00	0.00
0.90	0.00	28.01	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.14	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.28	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.41	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.55	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.69	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.83	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.96	0.00	0.00	0.00	0.00	0.00
1.70	0.00	29.10	0.00	0.00	0.00	0.00	0.00
1.80	0.00	29.24	0.00	0.00	0.00	0.00	0.00
1.90	0.00	29.38	0.00	0.00	0.00	0.00	0.00
2.00	0.00	29.51	0.00	0.00	0.00	0.00	0.00

Table 171: Put option prices for September Nino 3.4 SST conditioned on IRI ensemble forecasts released in May

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.87	23.74	0.00	0.90	1.00	1.00	1.00
-1.90	0.85	23.89	0.00	0.82	1.00	1.00	1.00
-1.80	0.83	24.04	0.00	0.75	1.00	1.00	1.00
-1.70	0.80	24.19	0.00	0.67	1.00	1.00	1.00
-1.60	0.77	24.34	0.00	0.60	0.99	1.00	1.00
-1.50	0.74	24.49	0.00	0.53	0.91	1.00	1.00
-1.40	0.69	24.64	0.00	0.45	0.81	1.00	1.00
-1.30	0.64	24.79	0.00	0.37	0.72	1.00	1.00
-1.20	0.59	24.94	0.00	0.29	0.63	0.97	1.00
-1.10	0.53	25.09	0.00	0.22	0.54	0.87	1.00
-1.00	0.47	25.24	0.00	0.14	0.45	0.77	1.00
-0.90	0.40	25.39	0.00	0.06	0.37	0.67	1.00
-0.80	0.34	25.53	0.00	0.00	0.28	0.57	1.00
-0.70	0.27	25.68	0.00	0.00	0.18	0.47	1.00
-0.60	0.22	25.84	0.00	0.00	0.09	0.37	0.97
-0.50	0.16	25.98	0.00	0.00	0.00	0.27	0.85
-0.40	0.12	26.14	0.00	0.00	0.00	0.17	0.73
-0.30	0.08	26.28	0.00	0.00	0.00	0.08	0.63
-0.20	0.06	26.43	0.00	0.00	0.00	0.00	0.53
-0.10	0.04	26.58	0.00	0.00	0.00	0.00	0.42
0.00	0.02	26.73	0.00	0.00	0.00	0.00	0.32
0.10	0.02	26.88	0.00	0.00	0.00	0.00	0.24
0.20	0.01	27.03	0.00	0.00	0.00	0.00	0.14
0.30	0.01	27.18	0.00	0.00	0.00	0.00	0.05
0.40	0.00	27.33	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.47	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.62	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.77	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.92	0.00	0.00	0.00	0.00	0.00
0.90	0.00	28.07	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.21	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.37	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.52	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.66	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.82	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.97	0.00	0.00	0.00	0.00	0.00
1.60	0.00	29.12	0.00	0.00	0.00	0.00	0.00
1.70	0.00	29.26	0.00	0.00	0.00	0.00	0.00
1.80	0.00	29.42	0.00	0.00	0.00	0.00	0.00
1.90	0.00	29.57	0.00	0.00	0.00	0.00	0.00
2.00	0.00	29.71	0.00	0.00	0.00	0.00	0.00

Table 172: Put option prices for September Nino 3.4 SST conditioned on IRI ensemble forecasts released in April

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.94	23.10	0.26	1.00	1.00	1.00	1.00
-1.90	0.93	23.28	0.23	1.00	1.00	1.00	1.00
-1.80	0.92	23.46	0.14	1.00	1.00	1.00	1.00
-1.70	0.90	23.64	0.10	1.00	1.00	1.00	1.00
-1.60	0.88	23.82	0.03	0.91	1.00	1.00	1.00
-1.50	0.86	24.00	0.00	0.82	1.00	1.00	1.00
-1.40	0.83	24.18	0.00	0.73	1.00	1.00	1.00
-1.30	0.79	24.36	0.00	0.63	0.98	1.00	1.00
-1.20	0.74	24.54	0.00	0.54	0.88	1.00	1.00
-1.10	0.68	24.71	0.00	0.45	0.77	1.00	1.00
-1.00	0.61	24.90	0.00	0.35	0.66	0.96	1.00
-0.90	0.54	25.08	0.00	0.26	0.55	0.84	1.00
-0.80	0.46	25.26	0.00	0.16	0.44	0.72	1.00
-0.70	0.37	25.44	0.00	0.06	0.33	0.60	1.00
-0.60	0.29	25.62	0.00	0.00	0.22	0.48	1.00
-0.50	0.22	25.80	0.00	0.00	0.12	0.37	0.91
-0.40	0.15	25.98	0.00	0.00	0.01	0.25	0.79
-0.30	0.10	26.16	0.00	0.00	0.00	0.13	0.65
-0.20	0.06	26.34	0.00	0.00	0.00	0.02	0.52
-0.10	0.04	26.51	0.00	0.00	0.00	0.00	0.40
0.00	0.02	26.70	0.00	0.00	0.00	0.00	0.28
0.10	0.01	26.88	0.00	0.00	0.00	0.00	0.17
0.20	0.01	27.06	0.00	0.00	0.00	0.00	0.07
0.30	0.00	27.24	0.00	0.00	0.00	0.00	0.00
0.40	0.00	27.42	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.60	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.78	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.97	0.00	0.00	0.00	0.00	0.00
0.80	0.00	28.14	0.00	0.00	0.00	0.00	0.00
0.90	0.00	28.32	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.51	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.68	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.87	0.00	0.00	0.00	0.00	0.00
1.30	0.00	29.04	0.00	0.00	0.00	0.00	0.00
1.40	0.00	29.22	0.00	0.00	0.00	0.00	0.00
1.50	0.00	29.40	0.00	0.00	0.00	0.00	0.00
1.60	0.00	29.58	0.00	0.00	0.00	0.00	0.00
1.70	0.00	29.77	0.00	0.00	0.00	0.00	0.00
1.80	0.00	29.94	0.00	0.00	0.00	0.00	0.00
1.90	0.00	30.12	0.00	0.00	0.00	0.00	0.00
2.00	0.00	30.30	0.00	0.00	0.00	0.00	0.00

Table 173: Put option prices for September Nino 3.4 SST conditioned on IRI ensemble forecasts released in March

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.81	23.61	0.00	0.75	1.00	1.00	1.00
-1.90	0.79	23.78	0.00	0.68	1.00	1.00	1.00
-1.80	0.77	23.93	0.00	0.62	1.00	1.00	1.00
-1.70	0.75	24.10	0.00	0.54	1.00	1.00	1.00
-1.60	0.73	24.26	0.00	0.47	1.00	1.00	1.00
-1.50	0.70	24.41	0.00	0.40	0.95	1.00	1.00
-1.40	0.67	24.57	0.00	0.34	0.86	1.00	1.00
-1.30	0.63	24.73	0.00	0.26	0.77	1.00	1.00
-1.20	0.58	24.89	0.00	0.19	0.66	1.00	1.00
-1.10	0.54	25.05	0.00	0.12	0.57	1.00	1.00
-1.00	0.48	25.21	0.00	0.04	0.47	0.90	1.00
-0.90	0.43	25.37	0.00	0.00	0.38	0.78	1.00
-0.80	0.37	25.52	0.00	0.00	0.28	0.67	1.00
-0.70	0.31	25.68	0.00	0.00	0.19	0.56	1.00
-0.60	0.25	25.84	0.00	0.00	0.09	0.44	1.00
-0.50	0.20	26.01	0.00	0.00	0.00	0.33	1.00
-0.40	0.15	26.16	0.00	0.00	0.00	0.22	0.93
-0.30	0.11	26.33	0.00	0.00	0.00	0.11	0.79
-0.20	0.08	26.48	0.00	0.00	0.00	0.01	0.68
-0.10	0.05	26.65	0.00	0.00	0.00	0.00	0.56
0.00	0.04	26.80	0.00	0.00	0.00	0.00	0.46
0.10	0.03	26.96	0.00	0.00	0.00	0.00	0.37
0.20	0.02	27.12	0.00	0.00	0.00	0.00	0.26
0.30	0.01	27.28	0.00	0.00	0.00	0.00	0.20
0.40	0.01	27.44	0.00	0.00	0.00	0.00	0.13
0.50	0.01	27.61	0.00	0.00	0.00	0.00	0.05
0.60	0.01	27.76	0.00	0.00	0.00	0.00	0.01
0.70	0.01	27.92	0.00	0.00	0.00	0.00	0.00
0.80	0.01	28.08	0.00	0.00	0.00	0.00	0.00
0.90	0.01	28.24	0.00	0.00	0.00	0.00	0.00
1.00	0.01	28.40	0.00	0.00	0.00	0.00	0.00
1.10	0.01	28.55	0.00	0.00	0.00	0.00	0.00
1.20	0.01	28.71	0.00	0.00	0.00	0.00	0.00
1.30	0.01	28.88	0.00	0.00	0.00	0.00	0.00
1.40	0.01	29.04	0.00	0.00	0.00	0.00	0.00
1.50	0.01	29.19	0.00	0.00	0.00	0.00	0.00
1.60	0.01	29.35	0.00	0.00	0.00	0.00	0.00
1.70	0.01	29.52	0.00	0.00	0.00	0.00	0.00
1.80	0.01	29.68	0.00	0.00	0.00	0.00	0.00
1.90	0.01	29.84	0.00	0.00	0.00	0.00	0.00
2.00	0.01	29.99	0.00	0.00	0.00	0.00	0.00

Table 174: Put option prices for September Nino 3.4 SST conditioned on IRI ensemble forecasts released in February

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.48	25.27	0.00	0.00	0.44	1.00	1.00
-1.90	0.47	25.34	0.00	0.00	0.40	1.00	1.00
-1.80	0.45	25.42	0.00	0.00	0.35	1.00	1.00
-1.70	0.44	25.48	0.00	0.00	0.31	1.00	1.00
-1.60	0.42	25.56	0.00	0.00	0.27	1.00	1.00
-1.50	0.40	25.64	0.00	0.00	0.21	0.98	1.00
-1.40	0.38	25.70	0.00	0.00	0.17	0.90	1.00
-1.30	0.36	25.78	0.00	0.00	0.13	0.83	1.00
-1.20	0.34	25.86	0.00	0.00	0.09	0.74	1.00
-1.10	0.32	25.92	0.00	0.00	0.04	0.67	1.00
-1.00	0.29	26.00	0.00	0.00	0.00	0.59	1.00
-0.90	0.27	26.08	0.00	0.00	0.00	0.50	1.00
-0.80	0.24	26.15	0.00	0.00	0.00	0.43	1.00
-0.70	0.21	26.22	0.00	0.00	0.00	0.36	1.00
-0.60	0.18	26.31	0.00	0.00	0.00	0.27	1.00
-0.50	0.16	26.38	0.00	0.00	0.00	0.21	1.00
-0.40	0.14	26.44	0.00	0.00	0.00	0.15	1.00
-0.30	0.12	26.52	0.00	0.00	0.00	0.08	0.99
-0.20	0.10	26.59	0.00	0.00	0.00	0.02	0.88
-0.10	0.09	26.66	0.00	0.00	0.00	0.00	0.84
0.00	0.07	26.73	0.00	0.00	0.00	0.00	0.76
0.10	0.06	26.82	0.00	0.00	0.00	0.00	0.73
0.20	0.06	26.88	0.00	0.00	0.00	0.00	0.68
0.30	0.06	26.96	0.00	0.00	0.00	0.00	0.69
0.40	0.05	27.02	0.00	0.00	0.00	0.00	0.70
0.50	0.06	27.11	0.00	0.00	0.00	0.00	0.73
0.60	0.05	27.18	0.00	0.00	0.00	0.00	0.72
0.70	0.06	27.25	0.00	0.00	0.00	0.00	0.79
0.80	0.06	27.33	0.00	0.00	0.00	0.00	0.83
0.90	0.06	27.40	0.00	0.00	0.00	0.00	0.88
1.00	0.07	27.48	0.00	0.00	0.00	0.00	0.94
1.10	0.07	27.54	0.00	0.00	0.00	0.00	1.00
1.20	0.07	27.62	0.00	0.00	0.00	0.00	1.00
1.30	0.08	27.69	0.00	0.00	0.00	0.00	1.00
1.40	0.08	27.77	0.00	0.00	0.00	0.00	1.00
1.50	0.09	27.83	0.00	0.00	0.00	0.00	1.00
1.60	0.09	27.92	0.00	0.00	0.00	0.00	1.00
1.70	0.09	27.99	0.00	0.00	0.00	0.00	1.00
1.80	0.10	28.06	0.00	0.00	0.00	0.00	1.00
1.90	0.10	28.13	0.00	0.00	0.00	0.00	1.00
2.00	0.11	28.21	0.00	0.00	0.00	0.00	1.00

Table 175: Put option prices for September Nino 3.4 SST conditioned on IRI ensemble forecasts released in January

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.45	25.55	0.00	0.00	0.26	1.00	1.00
-1.90	0.43	25.61	0.00	0.00	0.24	1.00	1.00
-1.80	0.42	25.67	0.00	0.00	0.21	1.00	1.00
-1.70	0.41	25.74	0.00	0.00	0.16	1.00	1.00
-1.60	0.39	25.79	0.00	0.00	0.12	1.00	1.00
-1.50	0.38	25.86	0.00	0.00	0.09	0.95	1.00
-1.40	0.36	25.92	0.00	0.00	0.05	0.87	1.00
-1.30	0.34	25.98	0.00	0.00	0.01	0.79	1.00
-1.20	0.32	26.05	0.00	0.00	0.00	0.70	1.00
-1.10	0.30	26.10	0.00	0.00	0.00	0.62	1.00
-1.00	0.27	26.17	0.00	0.00	0.00	0.54	1.00
-0.90	0.25	26.23	0.00	0.00	0.00	0.46	1.00
-0.80	0.23	26.28	0.00	0.00	0.00	0.39	1.00
-0.70	0.20	26.36	0.00	0.00	0.00	0.30	1.00
-0.60	0.17	26.43	0.00	0.00	0.00	0.23	1.00
-0.50	0.14	26.48	0.00	0.00	0.00	0.16	1.00
-0.40	0.12	26.54	0.00	0.00	0.00	0.10	1.00
-0.30	0.10	26.60	0.00	0.00	0.00	0.03	0.91
-0.20	0.08	26.66	0.00	0.00	0.00	0.00	0.82
-0.10	0.07	26.73	0.00	0.00	0.00	0.00	0.75
0.00	0.06	26.80	0.00	0.00	0.00	0.00	0.69
0.10	0.06	26.85	0.00	0.00	0.00	0.00	0.66
0.20	0.05	26.91	0.00	0.00	0.00	0.00	0.62
0.30	0.05	26.97	0.00	0.00	0.00	0.00	0.66
0.40	0.05	27.04	0.00	0.00	0.00	0.00	0.66
0.50	0.05	27.10	0.00	0.00	0.00	0.00	0.70
0.60	0.06	27.16	0.00	0.00	0.00	0.00	0.75
0.70	0.07	27.22	0.00	0.00	0.00	0.00	0.85
0.80	0.07	27.29	0.00	0.00	0.00	0.00	0.94
0.90	0.08	27.35	0.00	0.00	0.00	0.00	1.00
1.00	0.09	27.40	0.00	0.00	0.00	0.00	1.00
1.10	0.09	27.47	0.00	0.00	0.00	0.00	1.00
1.20	0.10	27.54	0.00	0.00	0.00	0.00	1.00
1.30	0.11	27.60	0.00	0.00	0.00	0.00	1.00
1.40	0.11	27.66	0.00	0.00	0.00	0.00	1.00
1.50	0.12	27.73	0.00	0.00	0.00	0.00	1.00
1.60	0.12	27.78	0.00	0.00	0.00	0.00	1.00
1.70	0.13	27.85	0.00	0.00	0.00	0.00	1.00
1.80	0.13	27.91	0.00	0.00	0.00	0.00	1.00
1.90	0.14	27.97	0.00	0.00	0.00	0.00	1.00
2.00	0.15	28.03	0.00	0.00	0.00	0.00	1.00

Table 176: Put option prices for September Nino 3.4 SST conditioned on IRI ensemble forecasts released in December

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.23	27.40	0.00	0.00	0.00	0.35	1.00
-1.90	0.22	27.37	0.00	0.00	0.00	0.31	1.00
-1.80	0.21	27.34	0.00	0.00	0.00	0.27	1.00
-1.70	0.21	27.32	0.00	0.00	0.00	0.25	1.00
-1.60	0.20	27.29	0.00	0.00	0.00	0.22	1.00
-1.50	0.19	27.26	0.00	0.00	0.00	0.17	1.00
-1.40	0.18	27.23	0.00	0.00	0.00	0.15	1.00
-1.30	0.17	27.20	0.00	0.00	0.00	0.11	1.00
-1.20	0.16	27.18	0.00	0.00	0.00	0.08	1.00
-1.10	0.15	27.15	0.00	0.00	0.00	0.05	1.00
-1.00	0.14	27.12	0.00	0.00	0.00	0.01	1.00
-0.90	0.13	27.09	0.00	0.00	0.00	0.00	1.00
-0.80	0.12	27.07	0.00	0.00	0.00	0.00	1.00
-0.70	0.11	27.04	0.00	0.00	0.00	0.00	1.00
-0.60	0.10	27.00	0.00	0.00	0.00	0.00	1.00
-0.50	0.09	26.98	0.00	0.00	0.00	0.00	0.98
-0.40	0.08	26.96	0.00	0.00	0.00	0.00	0.88
-0.30	0.07	26.93	0.00	0.00	0.00	0.00	0.80
-0.20	0.06	26.90	0.00	0.00	0.00	0.00	0.74
-0.10	0.06	26.87	0.00	0.00	0.00	0.00	0.69
0.00	0.06	26.84	0.00	0.00	0.00	0.00	0.69
0.10	0.06	26.81	0.00	0.00	0.00	0.00	0.70
0.20	0.06	26.79	0.00	0.00	0.00	0.00	0.71
0.30	0.07	26.77	0.00	0.00	0.00	0.00	0.75
0.40	0.08	26.74	0.00	0.00	0.00	0.00	0.84
0.50	0.10	26.71	0.00	0.00	0.00	0.00	0.94
0.60	0.11	26.68	0.00	0.00	0.00	0.04	1.00
0.70	0.13	26.66	0.00	0.00	0.00	0.08	1.00
0.80	0.15	26.62	0.00	0.00	0.00	0.14	1.00
0.90	0.17	26.60	0.00	0.00	0.00	0.20	1.00
1.00	0.19	26.57	0.00	0.00	0.00	0.27	1.00
1.10	0.21	26.54	0.00	0.00	0.00	0.33	1.00
1.20	0.23	26.52	0.00	0.00	0.00	0.38	1.00
1.30	0.25	26.48	0.00	0.00	0.00	0.45	1.00
1.40	0.26	26.46	0.00	0.00	0.00	0.51	1.00
1.50	0.28	26.43	0.00	0.00	0.00	0.59	1.00
1.60	0.29	26.41	0.00	0.00	0.00	0.64	1.00
1.70	0.30	26.37	0.00	0.00	0.00	0.72	1.00
1.80	0.32	26.36	0.00	0.00	0.00	0.77	1.00
1.90	0.33	26.32	0.00	0.00	0.00	0.85	1.00
2.00	0.34	26.29	0.00	0.00	0.00	0.91	1.00

Table 177: Put option prices for September Nino 3.4 SST conditioned on IRI ensemble forecasts released in November

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.17	28.18	0.00	0.00	0.00	0.00	1.00
-1.90	0.16	28.11	0.00	0.00	0.00	0.00	1.00
-1.80	0.16	28.05	0.00	0.00	0.00	0.00	1.00
-1.70	0.15	27.99	0.00	0.00	0.00	0.00	1.00
-1.60	0.15	27.92	0.00	0.00	0.00	0.00	1.00
-1.50	0.14	27.86	0.00	0.00	0.00	0.00	1.00
-1.40	0.14	27.80	0.00	0.00	0.00	0.00	1.00
-1.30	0.13	27.74	0.00	0.00	0.00	0.00	1.00
-1.20	0.12	27.68	0.00	0.00	0.00	0.00	1.00
-1.10	0.12	27.61	0.00	0.00	0.00	0.00	1.00
-1.00	0.11	27.55	0.00	0.00	0.00	0.00	1.00
-0.90	0.10	27.49	0.00	0.00	0.00	0.00	1.00
-0.80	0.09	27.42	0.00	0.00	0.00	0.00	1.00
-0.70	0.08	27.37	0.00	0.00	0.00	0.00	1.00
-0.60	0.08	27.30	0.00	0.00	0.00	0.00	0.99
-0.50	0.07	27.24	0.00	0.00	0.00	0.00	0.89
-0.40	0.07	27.16	0.00	0.00	0.00	0.00	0.82
-0.30	0.06	27.11	0.00	0.00	0.00	0.00	0.72
-0.20	0.05	27.05	0.00	0.00	0.00	0.00	0.68
-0.10	0.05	26.98	0.00	0.00	0.00	0.00	0.64
0.00	0.05	26.92	0.00	0.00	0.00	0.00	0.64
0.10	0.05	26.86	0.00	0.00	0.00	0.00	0.65
0.20	0.06	26.80	0.00	0.00	0.00	0.00	0.68
0.30	0.07	26.74	0.00	0.00	0.00	0.00	0.73
0.40	0.08	26.68	0.00	0.00	0.00	0.00	0.82
0.50	0.10	26.60	0.00	0.00	0.00	0.03	0.94
0.60	0.12	26.55	0.00	0.00	0.00	0.09	1.00
0.70	0.15	26.48	0.00	0.00	0.00	0.16	1.00
0.80	0.17	26.42	0.00	0.00	0.00	0.24	1.00
0.90	0.20	26.36	0.00	0.00	0.00	0.32	1.00
1.00	0.23	26.29	0.00	0.00	0.00	0.39	1.00
1.10	0.25	26.23	0.00	0.00	0.00	0.47	1.00
1.20	0.28	26.16	0.00	0.00	0.00	0.56	1.00
1.30	0.30	26.11	0.00	0.00	0.00	0.65	1.00
1.40	0.32	26.04	0.00	0.00	0.00	0.73	1.00
1.50	0.34	25.98	0.00	0.00	0.00	0.82	1.00
1.60	0.36	25.92	0.00	0.00	0.04	0.91	1.00
1.70	0.38	25.85	0.00	0.00	0.08	0.99	1.00
1.80	0.40	25.79	0.00	0.00	0.11	1.00	1.00
1.90	0.41	25.73	0.00	0.00	0.15	1.00	1.00
2.00	0.43	25.67	0.00	0.00	0.20	1.00	1.00

Appendix M: October Pricing

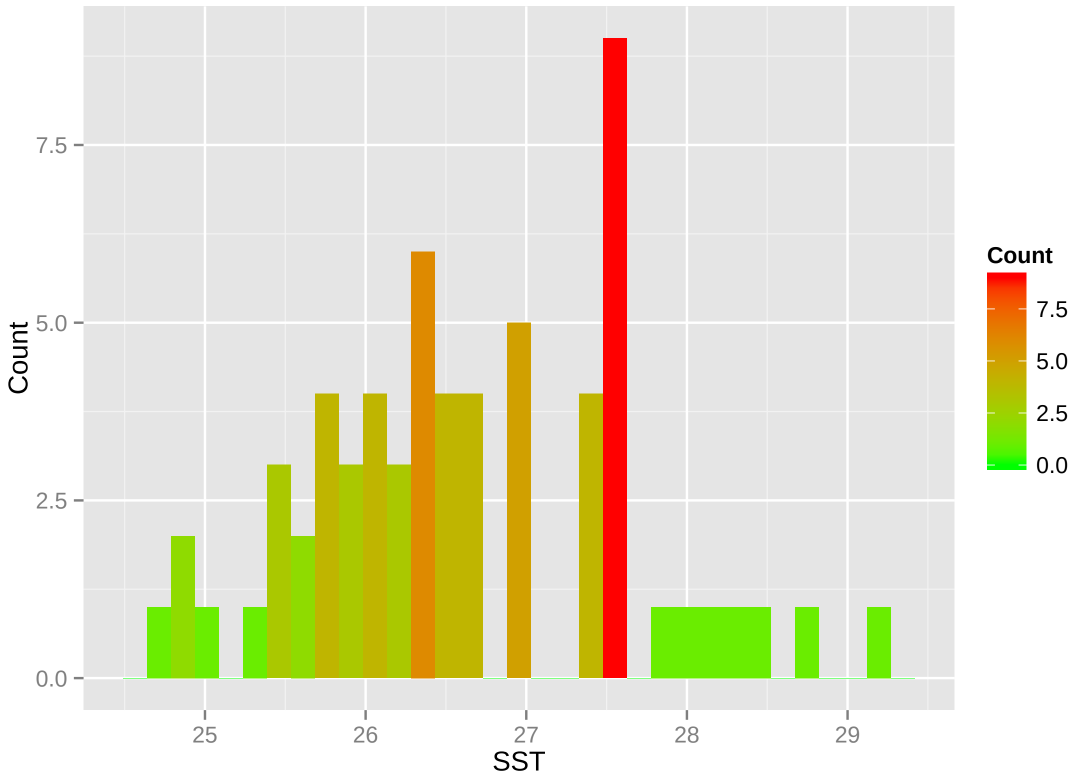


Figure 95: Histogram of October SST for Niño 3.4 ERSST.3b

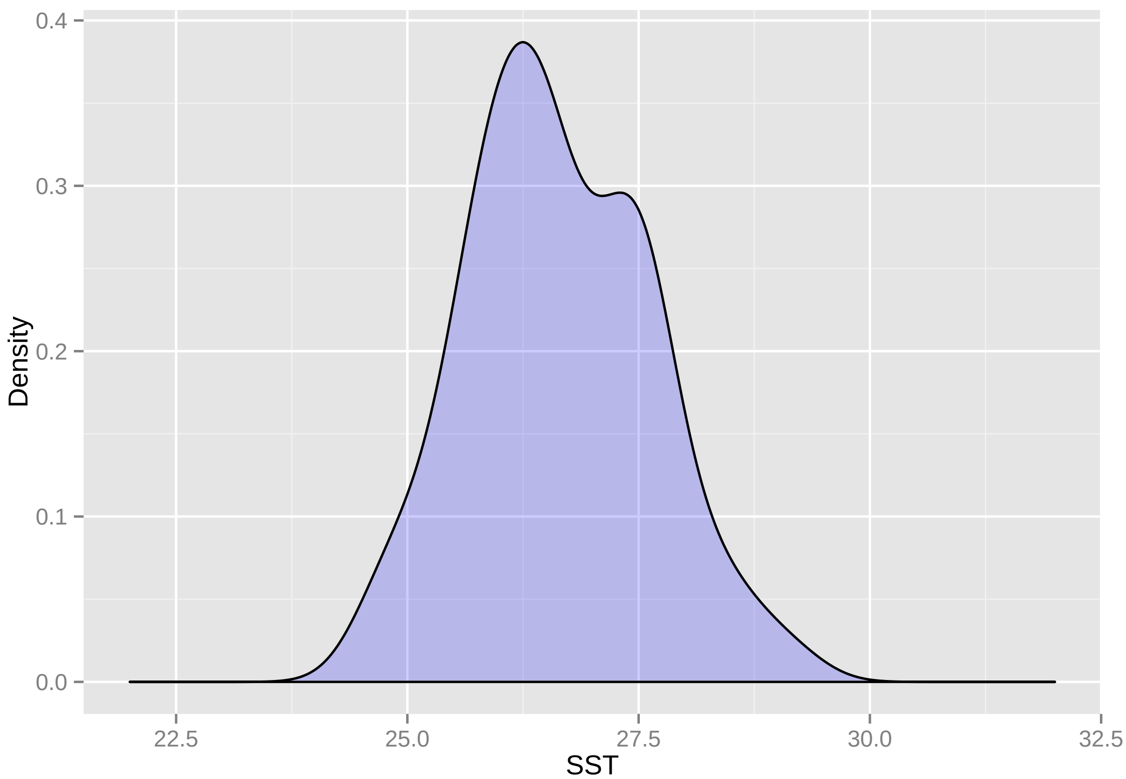


Figure 96: Kernel density estimate of October SST for Niño 3.4 ERSST.3b

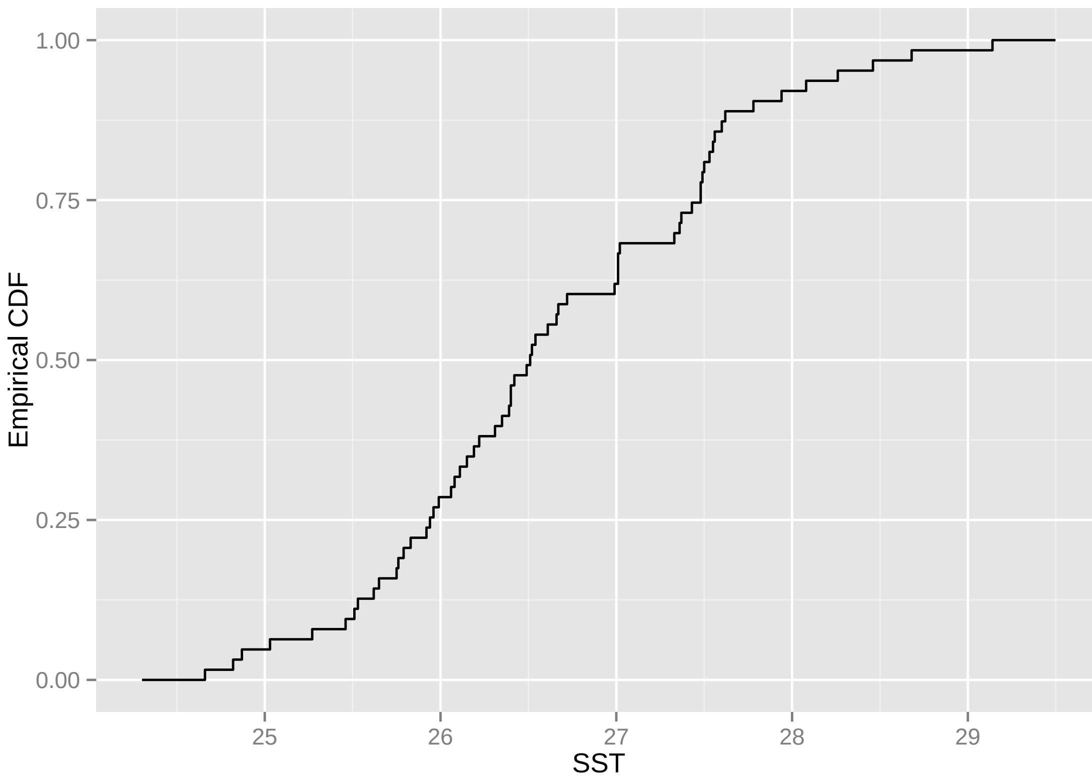


Figure 97: ECDF of October SST for Niño 3.4 ERSST.3b

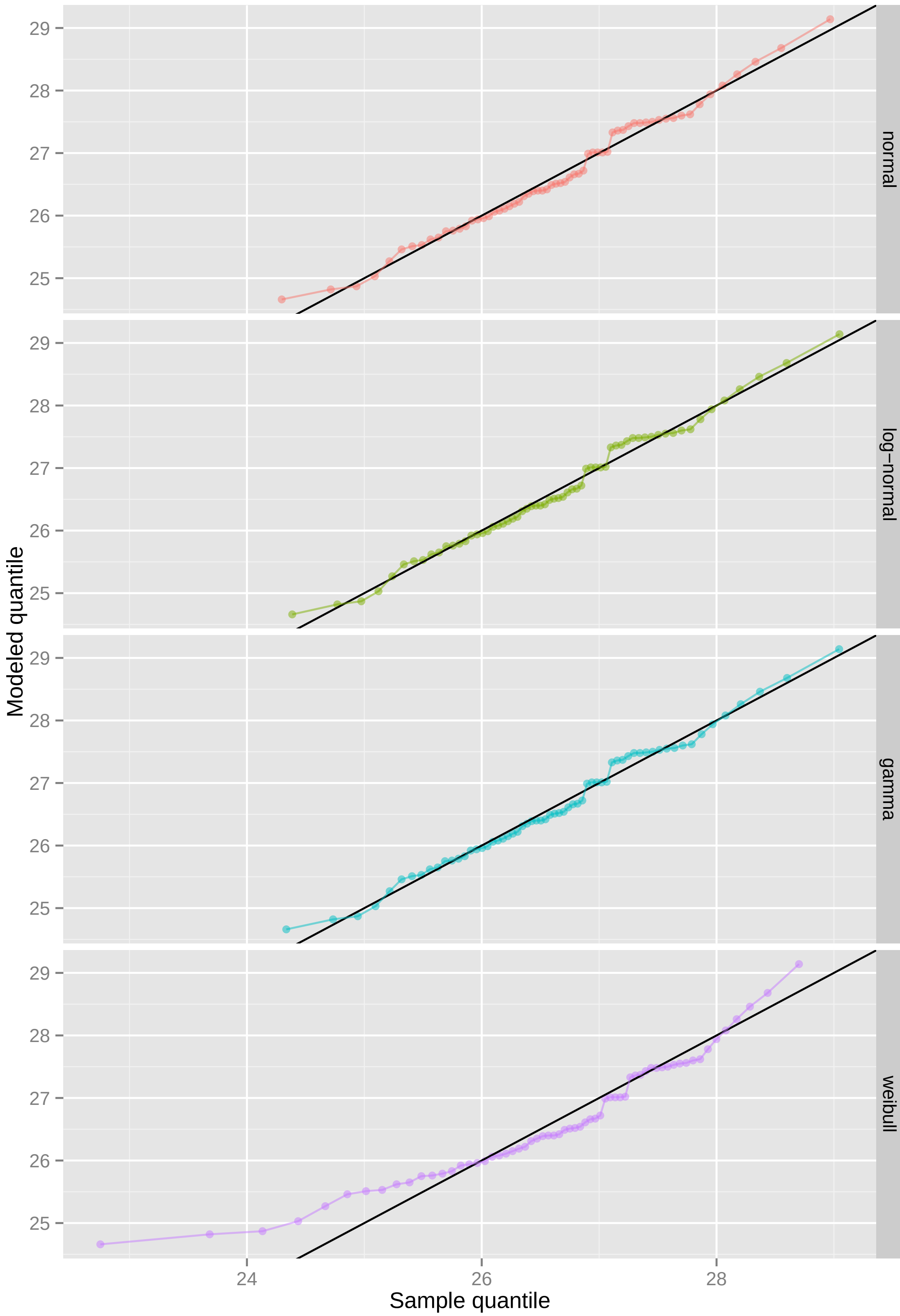


Figure 98: QQ plots of October SST for Niño 3.4 ERSST.3b compared to samples from various distributions (n=2 million)

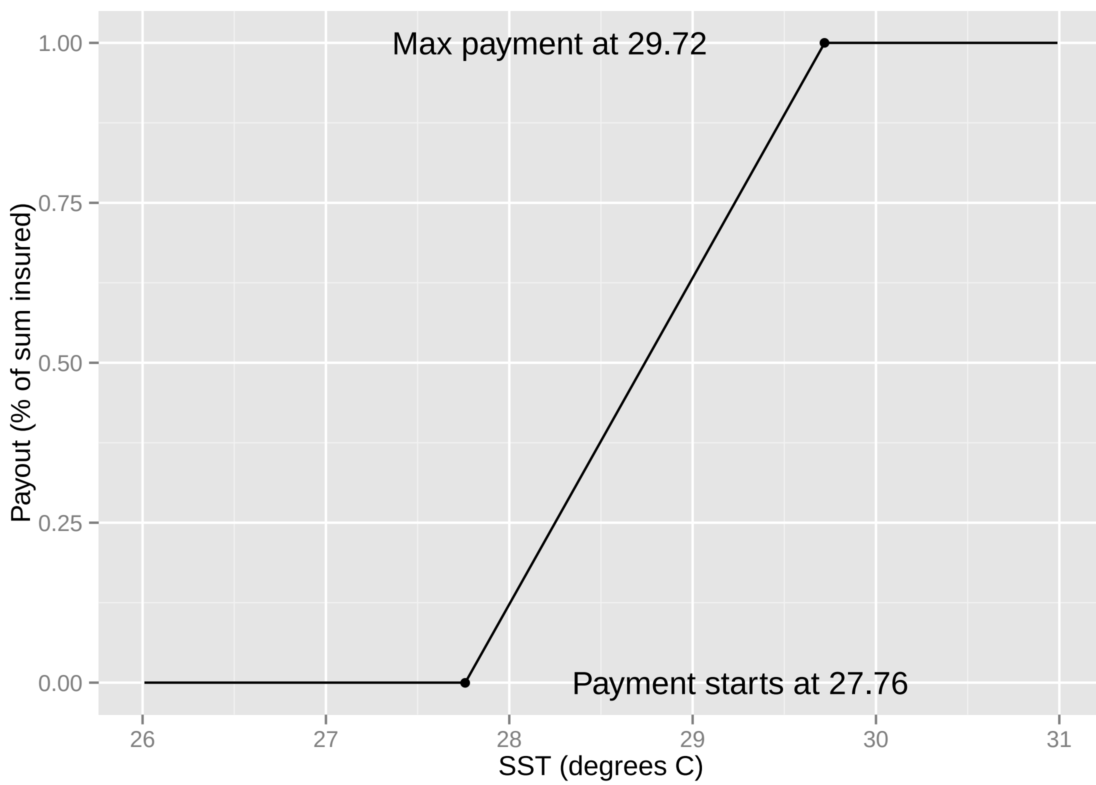


Figure 99: Payout function for call option on October SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations above the baseline

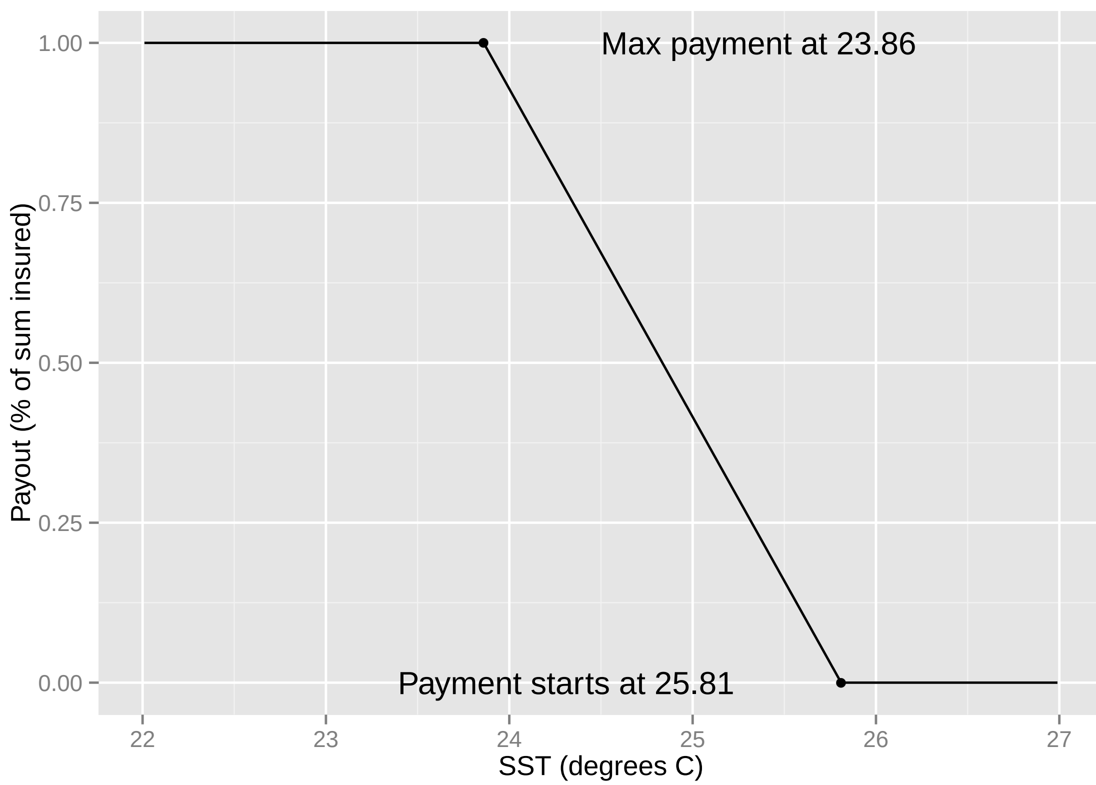


Figure 100: Payout function for put option on October SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

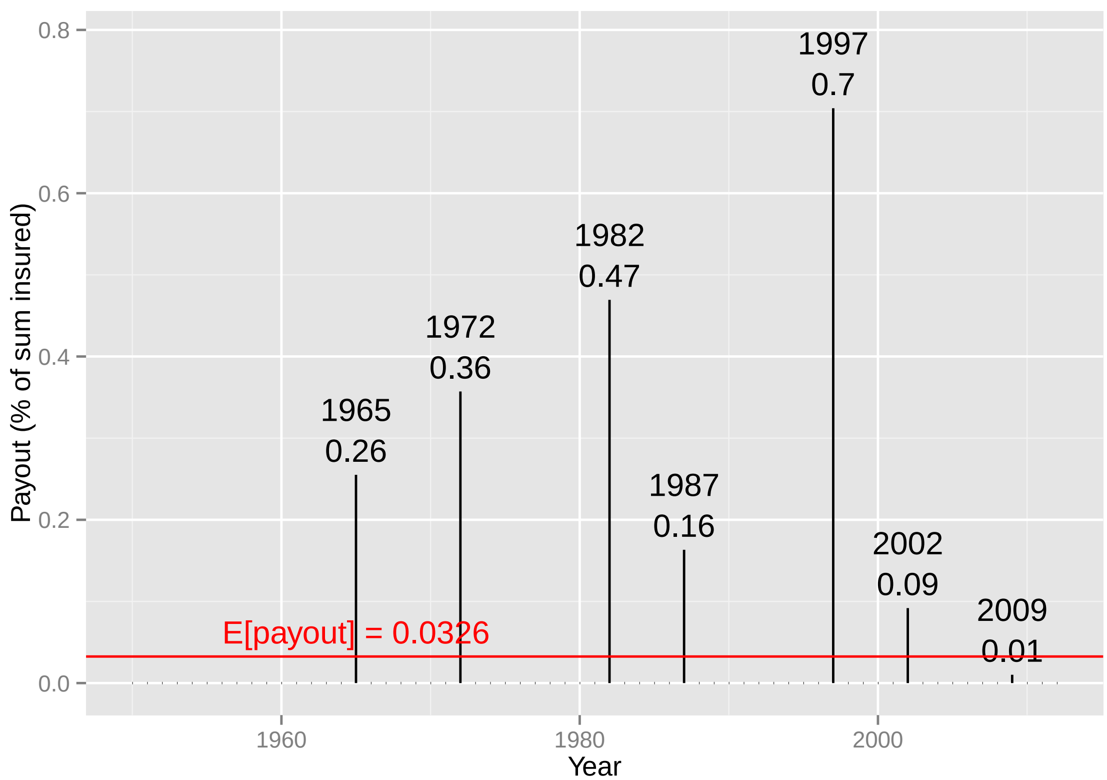


Figure 101: Historical burn on call option for October SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations above the baseline

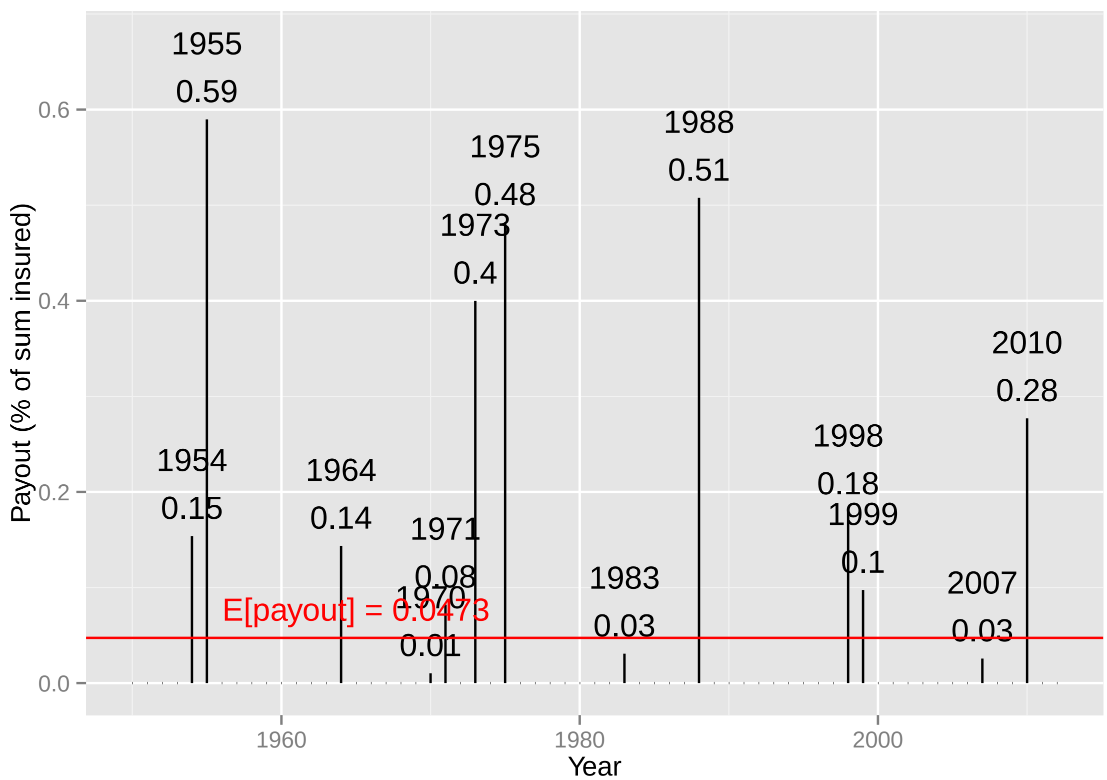


Figure 102: Historical burn on put option on October SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

Table 178: Bayesian regression linking October Niño 3.4 SST anomalies to average of relevant IRI ensemble forecasts

	mean	sd	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q	n_eff	Rhat
August forecast average covering October Niño 3.4 SST anomalies									
α	-0.10	0.10	-0.40	-0.20	-0.10	-0.10	0.10	91045	1
β	1.10	0.20	0.80	1.00	1.10	1.20	1.50	88920	1
σ_y^2	0.10	0.10	0.10	0.10	0.10	0.20	0.40	56829	1
July forecast average covering October Niño 3.4 SST anomalies									
α	-0.10	0.20	-0.50	-0.20	-0.10	0.00	0.20	92218	1
β	1.20	0.30	0.60	1.00	1.20	1.30	1.70	93712	1
σ_y^2	0.30	0.20	0.10	0.20	0.30	0.40	0.90	54297	1
June forecast average covering October Niño 3.4 SST anomalies									
α	-0.10	0.20	-0.40	-0.20	-0.10	0.00	0.30	95908	1
β	1.40	0.30	0.70	1.20	1.40	1.60	2.10	91107	1
σ_y^2	0.30	0.20	0.10	0.20	0.30	0.40	0.90	55596	1
May forecast average covering October Niño 3.4 SST anomalies									
α	-0.10	0.20	-0.50	-0.20	-0.10	0.10	0.40	92919	1
β	1.50	0.60	0.40	1.20	1.50	1.90	2.60	90255	1
σ_y^2	0.50	0.30	0.20	0.30	0.50	0.60	1.40	59205	1
April forecast average covering October Niño 3.4 SST anomalies									
α	-0.10	0.20	-0.50	-0.30	-0.10	0.00	0.30	88326	1
β	1.90	0.60	0.70	1.50	1.90	2.30	3.00	83902	1
σ_y^2	0.40	0.30	0.20	0.30	0.40	0.50	1.10	57674	1
March forecast average covering October Niño 3.4 SST anomalies									
α	0.00	0.20	-0.50	-0.10	0.00	0.20	0.50	101040	1
β	1.80	0.90	0.00	1.20	1.80	2.30	3.50	96782	1
σ_y^2	0.70	0.50	0.30	0.50	0.60	0.90	1.90	59539	1
February forecast average covering October Niño 3.4 SST anomalies									
α	-0.10	0.30	-0.70	-0.30	-0.10	0.10	0.60	98192	1
β	0.80	1.30	-1.80	0.00	0.80	1.60	3.40	88684	1
σ_y^2	1.10	0.80	0.40	0.60	0.90	1.30	3.20	54912	1
January forecast average covering October Niño 3.4 SST anomalies									
α	0.00	0.30	-0.60	-0.20	0.00	0.20	0.60	99518	1
β	1.00	1.60	-2.30	0.00	1.00	2.00	4.20	92225	1
σ_y^2	1.00	0.70	0.40	0.60	0.80	1.20	2.80	55715	1
December forecast average covering October Niño 3.4 SST anomalies									
α	0.00	0.30	-0.60	-0.20	0.00	0.30	0.70	80946	1
β	-0.30	1.90	-4.00	-1.40	-0.30	0.90	3.50	76663	1
σ_y^2	1.10	0.70	0.40	0.60	0.90	1.30	2.90	56323	1

Table 179: Call option prices for October Nino 3.4 SST conditioned on IRI ensemble forecasts released in August

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	24.35	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	24.46	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.58	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.69	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.81	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.92	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	25.04	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	25.15	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	25.27	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.38	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.50	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.61	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.73	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.84	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.95	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	26.07	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.18	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.30	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.41	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	26.53	0.00	0.00	0.00	0.00	0.00
0.00	0.00	26.64	0.00	0.00	0.00	0.00	0.00
0.10	0.00	26.75	0.00	0.00	0.00	0.00	0.00
0.20	0.00	26.87	0.00	0.00	0.00	0.00	0.00
0.30	0.00	26.99	0.00	0.00	0.00	0.00	0.00
0.40	0.00	27.10	0.00	0.00	0.00	0.00	0.07
0.50	0.01	27.21	0.00	0.00	0.00	0.00	0.12
0.60	0.01	27.33	0.00	0.00	0.00	0.00	0.18
0.70	0.02	27.44	0.00	0.00	0.00	0.00	0.24
0.80	0.04	27.56	0.00	0.00	0.00	0.02	0.31
0.90	0.06	27.67	0.00	0.00	0.00	0.08	0.37
1.00	0.09	27.79	0.00	0.00	0.01	0.15	0.43
1.10	0.12	27.90	0.00	0.00	0.07	0.20	0.49
1.20	0.16	28.01	0.00	0.00	0.13	0.26	0.56
1.30	0.21	28.13	0.00	0.06	0.19	0.33	0.63
1.40	0.26	28.25	0.00	0.11	0.25	0.39	0.70
1.50	0.32	28.36	0.00	0.17	0.31	0.45	0.76
1.60	0.37	28.48	0.00	0.22	0.36	0.51	0.82
1.70	0.43	28.59	0.00	0.28	0.42	0.57	0.89
1.80	0.48	28.71	0.00	0.34	0.48	0.63	0.96
1.90	0.54	28.82	0.05	0.39	0.54	0.69	1.00
2.00	0.59	28.93	0.10	0.45	0.60	0.75	1.00

Table 180: Call option prices for October Nino 3.4 SST conditioned on IRI ensemble forecasts released in July

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	24.36	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	24.47	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.59	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.70	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.82	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.93	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	25.05	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	25.17	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	25.29	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.40	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.51	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.63	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.74	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.86	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.97	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	26.09	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.20	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.32	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.43	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	26.55	0.00	0.00	0.00	0.00	0.00
0.00	0.01	26.66	0.00	0.00	0.00	0.00	0.05
0.10	0.01	26.78	0.00	0.00	0.00	0.00	0.11
0.20	0.01	26.89	0.00	0.00	0.00	0.00	0.17
0.30	0.02	27.01	0.00	0.00	0.00	0.00	0.23
0.40	0.02	27.12	0.00	0.00	0.00	0.00	0.28
0.50	0.03	27.24	0.00	0.00	0.00	0.00	0.36
0.60	0.05	27.36	0.00	0.00	0.00	0.00	0.42
0.70	0.06	27.47	0.00	0.00	0.00	0.05	0.48
0.80	0.08	27.59	0.00	0.00	0.00	0.11	0.54
0.90	0.11	27.70	0.00	0.00	0.00	0.17	0.62
1.00	0.14	27.81	0.00	0.00	0.03	0.23	0.70
1.10	0.18	27.93	0.00	0.00	0.09	0.29	0.76
1.20	0.21	28.04	0.00	0.00	0.14	0.36	0.83
1.30	0.26	28.16	0.00	0.00	0.21	0.42	0.89
1.40	0.31	28.28	0.00	0.05	0.26	0.48	0.98
1.50	0.35	28.39	0.00	0.10	0.32	0.54	1.00
1.60	0.40	28.51	0.00	0.16	0.38	0.61	1.00
1.70	0.45	28.62	0.00	0.21	0.44	0.67	1.00
1.80	0.50	28.74	0.00	0.26	0.50	0.74	1.00
1.90	0.55	28.85	0.00	0.31	0.56	0.80	1.00
2.00	0.59	28.97	0.00	0.37	0.62	0.86	1.00

Table 181: Call option prices for October Nino 3.4 SST conditioned on IRI ensemble forecasts released in June

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	23.93	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	24.07	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.21	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.35	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.49	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.63	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	24.77	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	24.91	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	25.05	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.19	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.33	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.47	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.60	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.74	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.88	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	26.02	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.16	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.30	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.44	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	26.58	0.00	0.00	0.00	0.00	0.02
0.00	0.01	26.72	0.00	0.00	0.00	0.00	0.09
0.10	0.01	26.86	0.00	0.00	0.00	0.00	0.16
0.20	0.02	26.99	0.00	0.00	0.00	0.00	0.22
0.30	0.02	27.14	0.00	0.00	0.00	0.00	0.30
0.40	0.04	27.27	0.00	0.00	0.00	0.00	0.38
0.50	0.05	27.41	0.00	0.00	0.00	0.02	0.45
0.60	0.08	27.55	0.00	0.00	0.00	0.09	0.54
0.70	0.11	27.69	0.00	0.00	0.00	0.17	0.61
0.80	0.14	27.83	0.00	0.00	0.04	0.24	0.69
0.90	0.19	27.97	0.00	0.00	0.11	0.32	0.78
1.00	0.24	28.11	0.00	0.00	0.18	0.39	0.86
1.10	0.29	28.24	0.00	0.03	0.25	0.47	0.95
1.20	0.35	28.38	0.00	0.09	0.32	0.54	1.00
1.30	0.41	28.53	0.00	0.16	0.39	0.62	1.00
1.40	0.47	28.67	0.00	0.22	0.46	0.70	1.00
1.50	0.53	28.80	0.00	0.28	0.53	0.78	1.00
1.60	0.58	28.95	0.00	0.35	0.60	0.86	1.00
1.70	0.64	29.08	0.00	0.42	0.68	0.93	1.00
1.80	0.69	29.23	0.00	0.48	0.75	1.00	1.00
1.90	0.73	29.36	0.00	0.54	0.82	1.00	1.00
2.00	0.77	29.51	0.00	0.61	0.89	1.00	1.00

Table 182: Call option prices for October Nino 3.4 SST conditioned on IRI ensemble forecasts released in May

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	23.64	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	23.79	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	23.95	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.10	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.26	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.41	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	24.56	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	24.72	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	24.87	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.02	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.17	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.32	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.47	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.63	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.78	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	25.94	0.00	0.00	0.00	0.00	0.00
-0.40	0.01	26.09	0.00	0.00	0.00	0.00	0.00
-0.30	0.01	26.24	0.00	0.00	0.00	0.00	0.05
-0.20	0.01	26.39	0.00	0.00	0.00	0.00	0.10
-0.10	0.01	26.55	0.00	0.00	0.00	0.00	0.18
0.00	0.02	26.70	0.00	0.00	0.00	0.00	0.24
0.10	0.02	26.85	0.00	0.00	0.00	0.00	0.31
0.20	0.03	27.01	0.00	0.00	0.00	0.00	0.40
0.30	0.05	27.16	0.00	0.00	0.00	0.00	0.47
0.40	0.07	27.31	0.00	0.00	0.00	0.02	0.56
0.50	0.09	27.46	0.00	0.00	0.00	0.10	0.66
0.60	0.12	27.62	0.00	0.00	0.00	0.18	0.75
0.70	0.16	27.77	0.00	0.00	0.01	0.27	0.85
0.80	0.21	27.93	0.00	0.00	0.09	0.36	0.95
0.90	0.26	28.08	0.00	0.00	0.16	0.44	1.00
1.00	0.31	28.23	0.00	0.00	0.24	0.53	1.00
1.10	0.37	28.39	0.00	0.02	0.32	0.61	1.00
1.20	0.43	28.53	0.00	0.09	0.40	0.70	1.00
1.30	0.48	28.69	0.00	0.15	0.47	0.79	1.00
1.40	0.54	28.85	0.00	0.22	0.55	0.89	1.00
1.50	0.59	28.99	0.00	0.28	0.63	0.97	1.00
1.60	0.63	29.14	0.00	0.35	0.71	1.00	1.00
1.70	0.68	29.30	0.00	0.42	0.79	1.00	1.00
1.80	0.71	29.45	0.00	0.49	0.87	1.00	1.00
1.90	0.75	29.60	0.00	0.54	0.94	1.00	1.00
2.00	0.78	29.76	0.00	0.61	1.00	1.00	1.00

Table 183: Call option prices for October Nino 3.4 SST conditioned on IRI ensemble forecasts released in April

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	22.87	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	23.06	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	23.24	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	23.44	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	23.62	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	23.81	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	24.00	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	24.19	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	24.38	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	24.56	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	24.76	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	24.94	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.13	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.32	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.51	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	25.70	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	25.88	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.08	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.26	0.00	0.00	0.00	0.00	0.00
-0.10	0.01	26.46	0.00	0.00	0.00	0.00	0.06
0.00	0.01	26.64	0.00	0.00	0.00	0.00	0.15
0.10	0.02	26.83	0.00	0.00	0.00	0.00	0.24
0.20	0.03	27.02	0.00	0.00	0.00	0.00	0.34
0.30	0.04	27.20	0.00	0.00	0.00	0.00	0.43
0.40	0.07	27.40	0.00	0.00	0.00	0.04	0.55
0.50	0.10	27.59	0.00	0.00	0.00	0.14	0.66
0.60	0.15	27.78	0.00	0.00	0.01	0.24	0.76
0.70	0.21	27.97	0.00	0.00	0.11	0.35	0.89
0.80	0.27	28.15	0.00	0.00	0.20	0.45	1.00
0.90	0.35	28.35	0.00	0.04	0.30	0.56	1.00
1.00	0.42	28.53	0.00	0.12	0.40	0.67	1.00
1.10	0.49	28.72	0.00	0.21	0.49	0.77	1.00
1.20	0.56	28.91	0.00	0.29	0.59	0.88	1.00
1.30	0.63	29.10	0.00	0.37	0.68	0.99	1.00
1.40	0.69	29.29	0.00	0.46	0.78	1.00	1.00
1.50	0.74	29.48	0.00	0.55	0.88	1.00	1.00
1.60	0.78	29.67	0.00	0.62	0.98	1.00	1.00
1.70	0.82	29.84	0.00	0.70	1.00	1.00	1.00
1.80	0.85	30.04	0.00	0.79	1.00	1.00	1.00
1.90	0.87	30.23	0.00	0.87	1.00	1.00	1.00
2.00	0.89	30.43	0.04	0.95	1.00	1.00	1.00

Table 184: Call option prices for October Nino 3.4 SST conditioned on IRI ensemble forecasts released in March

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.01	23.29	0.00	0.00	0.00	0.00	0.00
-1.90	0.01	23.47	0.00	0.00	0.00	0.00	0.00
-1.80	0.01	23.64	0.00	0.00	0.00	0.00	0.00
-1.70	0.01	23.81	0.00	0.00	0.00	0.00	0.00
-1.60	0.01	23.99	0.00	0.00	0.00	0.00	0.00
-1.50	0.01	24.17	0.00	0.00	0.00	0.00	0.00
-1.40	0.01	24.35	0.00	0.00	0.00	0.00	0.00
-1.30	0.01	24.52	0.00	0.00	0.00	0.00	0.00
-1.20	0.01	24.69	0.00	0.00	0.00	0.00	0.00
-1.10	0.01	24.87	0.00	0.00	0.00	0.00	0.00
-1.00	0.01	25.04	0.00	0.00	0.00	0.00	0.00
-0.90	0.01	25.21	0.00	0.00	0.00	0.00	0.00
-0.80	0.01	25.40	0.00	0.00	0.00	0.00	0.00
-0.70	0.01	25.57	0.00	0.00	0.00	0.00	0.02
-0.60	0.01	25.75	0.00	0.00	0.00	0.00	0.05
-0.50	0.01	25.92	0.00	0.00	0.00	0.00	0.11
-0.40	0.01	26.10	0.00	0.00	0.00	0.00	0.14
-0.30	0.01	26.28	0.00	0.00	0.00	0.00	0.20
-0.20	0.02	26.45	0.00	0.00	0.00	0.00	0.27
-0.10	0.02	26.62	0.00	0.00	0.00	0.00	0.34
0.00	0.03	26.80	0.00	0.00	0.00	0.00	0.42
0.10	0.04	26.97	0.00	0.00	0.00	0.00	0.51
0.20	0.06	27.15	0.00	0.00	0.00	0.00	0.62
0.30	0.09	27.33	0.00	0.00	0.00	0.07	0.73
0.40	0.12	27.50	0.00	0.00	0.00	0.16	0.83
0.50	0.17	27.67	0.00	0.00	0.00	0.26	0.95
0.60	0.21	27.85	0.00	0.00	0.04	0.37	1.00
0.70	0.27	28.03	0.00	0.00	0.14	0.47	1.00
0.80	0.33	28.20	0.00	0.00	0.22	0.58	1.00
0.90	0.39	28.38	0.00	0.00	0.32	0.69	1.00
1.00	0.44	28.55	0.00	0.01	0.40	0.80	1.00
1.10	0.50	28.73	0.00	0.09	0.49	0.90	1.00
1.20	0.55	28.90	0.00	0.15	0.58	1.00	1.00
1.30	0.59	29.08	0.00	0.22	0.68	1.00	1.00
1.40	0.63	29.25	0.00	0.29	0.76	1.00	1.00
1.50	0.67	29.42	0.00	0.34	0.85	1.00	1.00
1.60	0.70	29.61	0.00	0.42	0.94	1.00	1.00
1.70	0.73	29.78	0.00	0.48	1.00	1.00	1.00
1.80	0.75	29.96	0.00	0.55	1.00	1.00	1.00
1.90	0.77	30.13	0.00	0.61	1.00	1.00	1.00
2.00	0.79	30.30	0.00	0.67	1.00	1.00	1.00

Table 185: Call option prices for October Nino 3.4 SST conditioned on IRI ensemble forecasts released in February

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.09	25.05	0.00	0.00	0.00	0.00	1.00
-1.90	0.09	25.13	0.00	0.00	0.00	0.00	1.00
-1.80	0.09	25.21	0.00	0.00	0.00	0.00	1.00
-1.70	0.08	25.29	0.00	0.00	0.00	0.00	1.00
-1.60	0.08	25.37	0.00	0.00	0.00	0.00	1.00
-1.50	0.08	25.46	0.00	0.00	0.00	0.00	1.00
-1.40	0.07	25.54	0.00	0.00	0.00	0.00	1.00
-1.30	0.07	25.62	0.00	0.00	0.00	0.00	1.00
-1.20	0.06	25.70	0.00	0.00	0.00	0.00	0.97
-1.10	0.06	25.79	0.00	0.00	0.00	0.00	0.91
-1.00	0.06	25.86	0.00	0.00	0.00	0.00	0.83
-0.90	0.05	25.95	0.00	0.00	0.00	0.00	0.76
-0.80	0.05	26.04	0.00	0.00	0.00	0.00	0.71
-0.70	0.05	26.11	0.00	0.00	0.00	0.00	0.66
-0.60	0.04	26.19	0.00	0.00	0.00	0.00	0.62
-0.50	0.04	26.28	0.00	0.00	0.00	0.00	0.59
-0.40	0.04	26.37	0.00	0.00	0.00	0.00	0.57
-0.30	0.04	26.44	0.00	0.00	0.00	0.00	0.54
-0.20	0.04	26.53	0.00	0.00	0.00	0.00	0.54
-0.10	0.04	26.60	0.00	0.00	0.00	0.00	0.56
0.00	0.05	26.69	0.00	0.00	0.00	0.00	0.59
0.10	0.05	26.78	0.00	0.00	0.00	0.00	0.64
0.20	0.06	26.86	0.00	0.00	0.00	0.00	0.69
0.30	0.07	26.94	0.00	0.00	0.00	0.00	0.75
0.40	0.09	27.02	0.00	0.00	0.00	0.00	0.83
0.50	0.11	27.11	0.00	0.00	0.00	0.05	0.95
0.60	0.13	27.18	0.00	0.00	0.00	0.11	1.00
0.70	0.15	27.27	0.00	0.00	0.00	0.18	1.00
0.80	0.17	27.35	0.00	0.00	0.00	0.25	1.00
0.90	0.20	27.43	0.00	0.00	0.00	0.32	1.00
1.00	0.23	27.52	0.00	0.00	0.00	0.40	1.00
1.10	0.25	27.59	0.00	0.00	0.00	0.46	1.00
1.20	0.28	27.67	0.00	0.00	0.00	0.54	1.00
1.30	0.30	27.77	0.00	0.00	0.01	0.62	1.00
1.40	0.33	27.84	0.00	0.00	0.04	0.70	1.00
1.50	0.35	27.93	0.00	0.00	0.09	0.76	1.00
1.60	0.37	28.02	0.00	0.00	0.14	0.85	1.00
1.70	0.39	28.09	0.00	0.00	0.17	0.92	1.00
1.80	0.41	28.19	0.00	0.00	0.22	1.00	1.00
1.90	0.42	28.25	0.00	0.00	0.25	1.00	1.00
2.00	0.44	28.34	0.00	0.00	0.29	1.00	1.00

Table 186: Call option prices for October Nino 3.4 SST conditioned on IRI ensemble forecasts released in January

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.12	24.78	0.00	0.00	0.00	0.00	1.00
-1.90	0.11	24.88	0.00	0.00	0.00	0.00	1.00
-1.80	0.11	24.98	0.00	0.00	0.00	0.00	1.00
-1.70	0.11	25.08	0.00	0.00	0.00	0.00	1.00
-1.60	0.10	25.18	0.00	0.00	0.00	0.00	1.00
-1.50	0.10	25.28	0.00	0.00	0.00	0.00	1.00
-1.40	0.09	25.38	0.00	0.00	0.00	0.00	1.00
-1.30	0.09	25.47	0.00	0.00	0.00	0.00	1.00
-1.20	0.08	25.57	0.00	0.00	0.00	0.00	1.00
-1.10	0.08	25.67	0.00	0.00	0.00	0.00	1.00
-1.00	0.07	25.77	0.00	0.00	0.00	0.00	1.00
-0.90	0.07	25.87	0.00	0.00	0.00	0.00	0.95
-0.80	0.06	25.96	0.00	0.00	0.00	0.00	0.84
-0.70	0.06	26.07	0.00	0.00	0.00	0.00	0.78
-0.60	0.05	26.16	0.00	0.00	0.00	0.00	0.70
-0.50	0.05	26.26	0.00	0.00	0.00	0.00	0.66
-0.40	0.04	26.36	0.00	0.00	0.00	0.00	0.59
-0.30	0.04	26.46	0.00	0.00	0.00	0.00	0.55
-0.20	0.04	26.56	0.00	0.00	0.00	0.00	0.55
-0.10	0.04	26.66	0.00	0.00	0.00	0.00	0.53
0.00	0.05	26.76	0.00	0.00	0.00	0.00	0.57
0.10	0.06	26.85	0.00	0.00	0.00	0.00	0.61
0.20	0.07	26.95	0.00	0.00	0.00	0.00	0.69
0.30	0.08	27.05	0.00	0.00	0.00	0.00	0.78
0.40	0.11	27.15	0.00	0.00	0.00	0.07	0.91
0.50	0.13	27.25	0.00	0.00	0.00	0.14	1.00
0.60	0.17	27.35	0.00	0.00	0.00	0.23	1.00
0.70	0.20	27.45	0.00	0.00	0.00	0.31	1.00
0.80	0.23	27.55	0.00	0.00	0.00	0.40	1.00
0.90	0.26	27.65	0.00	0.00	0.00	0.49	1.00
1.00	0.29	27.74	0.00	0.00	0.00	0.58	1.00
1.10	0.32	27.85	0.00	0.00	0.04	0.68	1.00
1.20	0.35	27.94	0.00	0.00	0.09	0.77	1.00
1.30	0.38	28.05	0.00	0.00	0.15	0.87	1.00
1.40	0.40	28.13	0.00	0.00	0.19	0.96	1.00
1.50	0.42	28.24	0.00	0.00	0.24	1.00	1.00
1.60	0.44	28.34	0.00	0.00	0.29	1.00	1.00
1.70	0.45	28.43	0.00	0.00	0.34	1.00	1.00
1.80	0.47	28.54	0.00	0.00	0.40	1.00	1.00
1.90	0.49	28.64	0.00	0.00	0.45	1.00	1.00
2.00	0.50	28.74	0.00	0.00	0.50	1.00	1.00

Table 187: Call option prices for October Nino 3.4 SST conditioned on IRI ensemble forecasts released in December

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.36	27.36	0.00	0.00	0.00	1.00	1.00
-1.90	0.35	27.34	0.00	0.00	0.00	1.00	1.00
-1.80	0.34	27.31	0.00	0.00	0.00	0.94	1.00
-1.70	0.33	27.28	0.00	0.00	0.00	0.87	1.00
-1.60	0.31	27.25	0.00	0.00	0.00	0.79	1.00
-1.50	0.30	27.23	0.00	0.00	0.00	0.72	1.00
-1.40	0.29	27.20	0.00	0.00	0.00	0.65	1.00
-1.30	0.28	27.17	0.00	0.00	0.00	0.59	1.00
-1.20	0.26	27.15	0.00	0.00	0.00	0.52	1.00
-1.10	0.25	27.12	0.00	0.00	0.00	0.46	1.00
-1.00	0.23	27.10	0.00	0.00	0.00	0.38	1.00
-0.90	0.21	27.06	0.00	0.00	0.00	0.32	1.00
-0.80	0.19	27.05	0.00	0.00	0.00	0.27	1.00
-0.70	0.17	27.01	0.00	0.00	0.00	0.19	1.00
-0.60	0.15	26.99	0.00	0.00	0.00	0.14	1.00
-0.50	0.13	26.97	0.00	0.00	0.00	0.08	1.00
-0.40	0.11	26.93	0.00	0.00	0.00	0.02	1.00
-0.30	0.09	26.90	0.00	0.00	0.00	0.00	0.89
-0.20	0.08	26.87	0.00	0.00	0.00	0.00	0.78
-0.10	0.06	26.85	0.00	0.00	0.00	0.00	0.69
0.00	0.05	26.81	0.00	0.00	0.00	0.00	0.62
0.10	0.05	26.78	0.00	0.00	0.00	0.00	0.60
0.20	0.05	26.77	0.00	0.00	0.00	0.00	0.62
0.30	0.06	26.75	0.00	0.00	0.00	0.00	0.68
0.40	0.06	26.71	0.00	0.00	0.00	0.00	0.72
0.50	0.07	26.69	0.00	0.00	0.00	0.00	0.80
0.60	0.08	26.65	0.00	0.00	0.00	0.00	0.92
0.70	0.10	26.63	0.00	0.00	0.00	0.00	1.00
0.80	0.11	26.61	0.00	0.00	0.00	0.00	1.00
0.90	0.12	26.58	0.00	0.00	0.00	0.00	1.00
1.00	0.13	26.55	0.00	0.00	0.00	0.01	1.00
1.10	0.15	26.52	0.00	0.00	0.00	0.06	1.00
1.20	0.16	26.49	0.00	0.00	0.00	0.08	1.00
1.30	0.17	26.47	0.00	0.00	0.00	0.13	1.00
1.40	0.18	26.44	0.00	0.00	0.00	0.17	1.00
1.50	0.20	26.42	0.00	0.00	0.00	0.22	1.00
1.60	0.20	26.38	0.00	0.00	0.00	0.25	1.00
1.70	0.21	26.36	0.00	0.00	0.00	0.29	1.00
1.80	0.22	26.33	0.00	0.00	0.00	0.34	1.00
1.90	0.23	26.30	0.00	0.00	0.00	0.39	1.00
2.00	0.24	26.28	0.00	0.00	0.00	0.41	1.00

Table 188: Put option prices for October Nino 3.4 SST conditioned on IRI ensemble forecasts released in August

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.73	24.35	0.21	0.58	0.75	0.92	1.00
-1.90	0.68	24.46	0.16	0.53	0.69	0.86	1.00
-1.80	0.62	24.58	0.11	0.47	0.63	0.80	1.00
-1.70	0.57	24.69	0.06	0.42	0.57	0.73	1.00
-1.60	0.51	24.81	0.01	0.36	0.52	0.67	1.00
-1.50	0.46	24.92	0.00	0.30	0.46	0.61	0.94
-1.40	0.40	25.04	0.00	0.25	0.40	0.55	0.88
-1.30	0.35	25.15	0.00	0.19	0.34	0.49	0.81
-1.20	0.29	25.27	0.00	0.13	0.28	0.42	0.74
-1.10	0.24	25.38	0.00	0.08	0.22	0.36	0.68
-1.00	0.19	25.50	0.00	0.02	0.16	0.30	0.61
-0.90	0.15	25.61	0.00	0.00	0.10	0.24	0.54
-0.80	0.11	25.73	0.00	0.00	0.04	0.18	0.48
-0.70	0.08	25.84	0.00	0.00	0.00	0.12	0.41
-0.60	0.05	25.95	0.00	0.00	0.00	0.06	0.35
-0.50	0.03	26.07	0.00	0.00	0.00	0.00	0.28
-0.40	0.02	26.18	0.00	0.00	0.00	0.00	0.22
-0.30	0.01	26.30	0.00	0.00	0.00	0.00	0.16
-0.20	0.01	26.41	0.00	0.00	0.00	0.00	0.10
-0.10	0.00	26.53	0.00	0.00	0.00	0.00	0.03
0.00	0.00	26.64	0.00	0.00	0.00	0.00	0.00
0.10	0.00	26.75	0.00	0.00	0.00	0.00	0.00
0.20	0.00	26.87	0.00	0.00	0.00	0.00	0.00
0.30	0.00	26.99	0.00	0.00	0.00	0.00	0.00
0.40	0.00	27.10	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.21	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.33	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.44	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.56	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.67	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.79	0.00	0.00	0.00	0.00	0.00
1.10	0.00	27.90	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.01	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.13	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.25	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.36	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.48	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.59	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.71	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.82	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.93	0.00	0.00	0.00	0.00	0.00

Table 189: Put option prices for October Nino 3.4 SST conditioned on IRI ensemble forecasts released in July

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.68	24.36	0.00	0.48	0.75	1.00	1.00
-1.90	0.64	24.47	0.00	0.42	0.69	0.94	1.00
-1.80	0.60	24.59	0.00	0.37	0.63	0.88	1.00
-1.70	0.55	24.70	0.00	0.32	0.57	0.82	1.00
-1.60	0.51	24.82	0.00	0.26	0.51	0.75	1.00
-1.50	0.46	24.93	0.00	0.21	0.45	0.69	1.00
-1.40	0.41	25.05	0.00	0.16	0.39	0.62	1.00
-1.30	0.36	25.17	0.00	0.10	0.33	0.56	1.00
-1.20	0.31	25.29	0.00	0.05	0.27	0.49	0.98
-1.10	0.26	25.40	0.00	0.00	0.21	0.43	0.91
-1.00	0.22	25.51	0.00	0.00	0.15	0.36	0.85
-0.90	0.18	25.63	0.00	0.00	0.09	0.30	0.78
-0.80	0.15	25.74	0.00	0.00	0.04	0.24	0.71
-0.70	0.11	25.86	0.00	0.00	0.00	0.18	0.63
-0.60	0.09	25.97	0.00	0.00	0.00	0.11	0.56
-0.50	0.06	26.09	0.00	0.00	0.00	0.05	0.49
-0.40	0.05	26.20	0.00	0.00	0.00	0.00	0.43
-0.30	0.03	26.32	0.00	0.00	0.00	0.00	0.36
-0.20	0.03	26.43	0.00	0.00	0.00	0.00	0.31
-0.10	0.02	26.55	0.00	0.00	0.00	0.00	0.24
0.00	0.01	26.66	0.00	0.00	0.00	0.00	0.18
0.10	0.01	26.78	0.00	0.00	0.00	0.00	0.11
0.20	0.01	26.89	0.00	0.00	0.00	0.00	0.06
0.30	0.00	27.01	0.00	0.00	0.00	0.00	0.00
0.40	0.00	27.12	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.24	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.36	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.47	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.59	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.70	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.81	0.00	0.00	0.00	0.00	0.00
1.10	0.00	27.93	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.04	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.16	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.28	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.39	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.51	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.62	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.74	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.85	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.97	0.00	0.00	0.00	0.00	0.00

Table 190: Put option prices for October Nino 3.4 SST conditioned on IRI ensemble forecasts released in June

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.80	23.93	0.00	0.66	0.96	1.00	1.00
-1.90	0.77	24.07	0.00	0.59	0.89	1.00	1.00
-1.80	0.73	24.21	0.00	0.54	0.82	1.00	1.00
-1.70	0.68	24.35	0.00	0.47	0.75	1.00	1.00
-1.60	0.64	24.49	0.00	0.41	0.68	0.95	1.00
-1.50	0.58	24.63	0.00	0.34	0.60	0.87	1.00
-1.40	0.53	24.77	0.00	0.28	0.54	0.79	1.00
-1.30	0.47	24.91	0.00	0.21	0.47	0.71	1.00
-1.20	0.41	25.05	0.00	0.15	0.39	0.63	1.00
-1.10	0.35	25.19	0.00	0.08	0.32	0.55	1.00
-1.00	0.30	25.33	0.00	0.02	0.25	0.48	0.99
-0.90	0.24	25.47	0.00	0.00	0.18	0.40	0.90
-0.80	0.19	25.60	0.00	0.00	0.11	0.33	0.81
-0.70	0.15	25.74	0.00	0.00	0.03	0.25	0.72
-0.60	0.11	25.88	0.00	0.00	0.00	0.17	0.63
-0.50	0.08	26.02	0.00	0.00	0.00	0.10	0.55
-0.40	0.06	26.16	0.00	0.00	0.00	0.02	0.46
-0.30	0.04	26.30	0.00	0.00	0.00	0.00	0.38
-0.20	0.02	26.44	0.00	0.00	0.00	0.00	0.31
-0.10	0.02	26.58	0.00	0.00	0.00	0.00	0.23
0.00	0.01	26.72	0.00	0.00	0.00	0.00	0.16
0.10	0.01	26.86	0.00	0.00	0.00	0.00	0.08
0.20	0.00	26.99	0.00	0.00	0.00	0.00	0.01
0.30	0.00	27.14	0.00	0.00	0.00	0.00	0.00
0.40	0.00	27.27	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.41	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.55	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.69	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.83	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.97	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.11	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.24	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.38	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.53	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.67	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.80	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.95	0.00	0.00	0.00	0.00	0.00
1.70	0.00	29.08	0.00	0.00	0.00	0.00	0.00
1.80	0.00	29.23	0.00	0.00	0.00	0.00	0.00
1.90	0.00	29.36	0.00	0.00	0.00	0.00	0.00
2.00	0.00	29.51	0.00	0.00	0.00	0.00	0.00

Table 191: Put option prices for October Nino 3.4 SST conditioned on IRI ensemble forecasts released in May

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.80	23.64	0.00	0.66	1.00	1.00	1.00
-1.90	0.77	23.79	0.00	0.60	1.00	1.00	1.00
-1.80	0.74	23.95	0.00	0.54	0.96	1.00	1.00
-1.70	0.71	24.10	0.00	0.47	0.88	1.00	1.00
-1.60	0.67	24.26	0.00	0.41	0.80	1.00	1.00
-1.50	0.64	24.41	0.00	0.34	0.72	1.00	1.00
-1.40	0.59	24.56	0.00	0.28	0.64	1.00	1.00
-1.30	0.54	24.72	0.00	0.21	0.56	0.91	1.00
-1.20	0.49	24.87	0.00	0.15	0.48	0.82	1.00
-1.10	0.44	25.02	0.00	0.08	0.41	0.73	1.00
-1.00	0.38	25.17	0.00	0.02	0.33	0.64	1.00
-0.90	0.32	25.32	0.00	0.00	0.25	0.55	1.00
-0.80	0.27	25.47	0.00	0.00	0.17	0.47	1.00
-0.70	0.22	25.63	0.00	0.00	0.10	0.38	1.00
-0.60	0.17	25.78	0.00	0.00	0.02	0.29	0.90
-0.50	0.13	25.94	0.00	0.00	0.00	0.20	0.78
-0.40	0.10	26.09	0.00	0.00	0.00	0.12	0.68
-0.30	0.07	26.24	0.00	0.00	0.00	0.03	0.59
-0.20	0.05	26.39	0.00	0.00	0.00	0.00	0.50
-0.10	0.03	26.55	0.00	0.00	0.00	0.00	0.41
0.00	0.02	26.70	0.00	0.00	0.00	0.00	0.32
0.10	0.02	26.85	0.00	0.00	0.00	0.00	0.24
0.20	0.01	27.01	0.00	0.00	0.00	0.00	0.17
0.30	0.01	27.16	0.00	0.00	0.00	0.00	0.10
0.40	0.01	27.31	0.00	0.00	0.00	0.00	0.02
0.50	0.00	27.46	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.62	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.77	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.93	0.00	0.00	0.00	0.00	0.00
0.90	0.00	28.08	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.23	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.39	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.53	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.69	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.85	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.99	0.00	0.00	0.00	0.00	0.00
1.60	0.00	29.14	0.00	0.00	0.00	0.00	0.00
1.70	0.00	29.30	0.00	0.00	0.00	0.00	0.00
1.80	0.00	29.45	0.00	0.00	0.00	0.00	0.00
1.90	0.00	29.60	0.00	0.00	0.00	0.00	0.00
2.00	0.00	29.76	0.00	0.00	0.00	0.00	0.00

Table 192: Put option prices for October Nino 3.4 SST conditioned on IRI ensemble forecasts released in April

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.91	22.87	0.05	1.00	1.00	1.00	1.00
-1.90	0.89	23.06	0.00	0.97	1.00	1.00	1.00
-1.80	0.88	23.24	0.00	0.90	1.00	1.00	1.00
-1.70	0.85	23.44	0.00	0.81	1.00	1.00	1.00
-1.60	0.83	23.62	0.00	0.73	1.00	1.00	1.00
-1.50	0.79	23.81	0.00	0.65	1.00	1.00	1.00
-1.40	0.75	24.00	0.00	0.56	0.93	1.00	1.00
-1.30	0.71	24.19	0.00	0.49	0.84	1.00	1.00
-1.20	0.66	24.38	0.00	0.40	0.74	1.00	1.00
-1.10	0.60	24.56	0.00	0.32	0.64	0.95	1.00
-1.00	0.53	24.76	0.00	0.24	0.54	0.84	1.00
-0.90	0.46	24.94	0.00	0.15	0.45	0.74	1.00
-0.80	0.39	25.13	0.00	0.07	0.35	0.63	1.00
-0.70	0.32	25.32	0.00	0.00	0.25	0.52	1.00
-0.60	0.25	25.51	0.00	0.00	0.16	0.42	0.98
-0.50	0.18	25.70	0.00	0.00	0.06	0.31	0.87
-0.40	0.13	25.88	0.00	0.00	0.00	0.21	0.75
-0.30	0.09	26.08	0.00	0.00	0.00	0.10	0.62
-0.20	0.06	26.26	0.00	0.00	0.00	0.00	0.51
-0.10	0.03	26.46	0.00	0.00	0.00	0.00	0.39
0.00	0.02	26.64	0.00	0.00	0.00	0.00	0.29
0.10	0.01	26.83	0.00	0.00	0.00	0.00	0.19
0.20	0.01	27.02	0.00	0.00	0.00	0.00	0.10
0.30	0.00	27.20	0.00	0.00	0.00	0.00	0.00
0.40	0.00	27.40	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.59	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.78	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.97	0.00	0.00	0.00	0.00	0.00
0.80	0.00	28.15	0.00	0.00	0.00	0.00	0.00
0.90	0.00	28.35	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.53	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.72	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.91	0.00	0.00	0.00	0.00	0.00
1.30	0.00	29.10	0.00	0.00	0.00	0.00	0.00
1.40	0.00	29.29	0.00	0.00	0.00	0.00	0.00
1.50	0.00	29.48	0.00	0.00	0.00	0.00	0.00
1.60	0.00	29.67	0.00	0.00	0.00	0.00	0.00
1.70	0.00	29.84	0.00	0.00	0.00	0.00	0.00
1.80	0.00	30.04	0.00	0.00	0.00	0.00	0.00
1.90	0.00	30.23	0.00	0.00	0.00	0.00	0.00
2.00	0.00	30.43	0.00	0.00	0.00	0.00	0.00

Table 193: Put option prices for October Nino 3.4 SST conditioned on IRI ensemble forecasts released in March

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.78	23.29	0.00	0.64	1.00	1.00	1.00
-1.90	0.76	23.47	0.00	0.57	1.00	1.00	1.00
-1.80	0.74	23.64	0.00	0.51	1.00	1.00	1.00
-1.70	0.72	23.81	0.00	0.45	1.00	1.00	1.00
-1.60	0.69	23.99	0.00	0.38	0.93	1.00	1.00
-1.50	0.66	24.17	0.00	0.32	0.85	1.00	1.00
-1.40	0.62	24.35	0.00	0.25	0.75	1.00	1.00
-1.30	0.59	24.52	0.00	0.19	0.66	1.00	1.00
-1.20	0.54	24.69	0.00	0.12	0.57	1.00	1.00
-1.10	0.49	24.87	0.00	0.05	0.49	0.93	1.00
-1.00	0.44	25.04	0.00	0.00	0.39	0.80	1.00
-0.90	0.39	25.21	0.00	0.00	0.30	0.70	1.00
-0.80	0.33	25.40	0.00	0.00	0.21	0.59	1.00
-0.70	0.27	25.57	0.00	0.00	0.13	0.48	1.00
-0.60	0.22	25.75	0.00	0.00	0.03	0.37	1.00
-0.50	0.17	25.92	0.00	0.00	0.00	0.27	0.98
-0.40	0.12	26.10	0.00	0.00	0.00	0.16	0.85
-0.30	0.09	26.28	0.00	0.00	0.00	0.06	0.72
-0.20	0.06	26.45	0.00	0.00	0.00	0.00	0.61
-0.10	0.04	26.62	0.00	0.00	0.00	0.00	0.49
0.00	0.03	26.80	0.00	0.00	0.00	0.00	0.39
0.10	0.02	26.97	0.00	0.00	0.00	0.00	0.31
0.20	0.02	27.15	0.00	0.00	0.00	0.00	0.23
0.30	0.01	27.33	0.00	0.00	0.00	0.00	0.16
0.40	0.01	27.50	0.00	0.00	0.00	0.00	0.10
0.50	0.01	27.67	0.00	0.00	0.00	0.00	0.04
0.60	0.01	27.85	0.00	0.00	0.00	0.00	0.00
0.70	0.01	28.03	0.00	0.00	0.00	0.00	0.00
0.80	0.01	28.20	0.00	0.00	0.00	0.00	0.00
0.90	0.01	28.38	0.00	0.00	0.00	0.00	0.00
1.00	0.01	28.55	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.73	0.00	0.00	0.00	0.00	0.00
1.20	0.01	28.90	0.00	0.00	0.00	0.00	0.00
1.30	0.01	29.08	0.00	0.00	0.00	0.00	0.00
1.40	0.01	29.25	0.00	0.00	0.00	0.00	0.00
1.50	0.01	29.42	0.00	0.00	0.00	0.00	0.00
1.60	0.01	29.61	0.00	0.00	0.00	0.00	0.00
1.70	0.01	29.78	0.00	0.00	0.00	0.00	0.00
1.80	0.01	29.96	0.00	0.00	0.00	0.00	0.00
1.90	0.01	30.13	0.00	0.00	0.00	0.00	0.00
2.00	0.01	30.30	0.00	0.00	0.00	0.00	0.00

Table 194: Put option prices for October Nino 3.4 SST conditioned on IRI ensemble forecasts released in February

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.47	25.05	0.00	0.00	0.39	1.00	1.00
-1.90	0.46	25.13	0.00	0.00	0.35	1.00	1.00
-1.80	0.44	25.21	0.00	0.00	0.31	1.00	1.00
-1.70	0.42	25.29	0.00	0.00	0.27	1.00	1.00
-1.60	0.41	25.37	0.00	0.00	0.23	0.99	1.00
-1.50	0.39	25.46	0.00	0.00	0.18	0.90	1.00
-1.40	0.37	25.54	0.00	0.00	0.14	0.82	1.00
-1.30	0.35	25.62	0.00	0.00	0.10	0.75	1.00
-1.20	0.32	25.70	0.00	0.00	0.06	0.67	1.00
-1.10	0.30	25.79	0.00	0.00	0.02	0.59	1.00
-1.00	0.27	25.86	0.00	0.00	0.00	0.52	1.00
-0.90	0.25	25.95	0.00	0.00	0.00	0.45	1.00
-0.80	0.22	26.04	0.00	0.00	0.00	0.37	1.00
-0.70	0.19	26.11	0.00	0.00	0.00	0.31	1.00
-0.60	0.17	26.19	0.00	0.00	0.00	0.24	1.00
-0.50	0.14	26.28	0.00	0.00	0.00	0.17	1.00
-0.40	0.12	26.37	0.00	0.00	0.00	0.10	0.98
-0.30	0.10	26.44	0.00	0.00	0.00	0.05	0.89
-0.20	0.08	26.53	0.00	0.00	0.00	0.00	0.79
-0.10	0.07	26.60	0.00	0.00	0.00	0.00	0.74
0.00	0.06	26.69	0.00	0.00	0.00	0.00	0.69
0.10	0.05	26.78	0.00	0.00	0.00	0.00	0.63
0.20	0.05	26.86	0.00	0.00	0.00	0.00	0.60
0.30	0.05	26.94	0.00	0.00	0.00	0.00	0.61
0.40	0.04	27.02	0.00	0.00	0.00	0.00	0.59
0.50	0.05	27.11	0.00	0.00	0.00	0.00	0.60
0.60	0.05	27.18	0.00	0.00	0.00	0.00	0.64
0.70	0.05	27.27	0.00	0.00	0.00	0.00	0.68
0.80	0.05	27.35	0.00	0.00	0.00	0.00	0.72
0.90	0.05	27.43	0.00	0.00	0.00	0.00	0.78
1.00	0.06	27.52	0.00	0.00	0.00	0.00	0.81
1.10	0.06	27.59	0.00	0.00	0.00	0.00	0.89
1.20	0.07	27.67	0.00	0.00	0.00	0.00	0.96
1.30	0.07	27.77	0.00	0.00	0.00	0.00	1.00
1.40	0.07	27.84	0.00	0.00	0.00	0.00	1.00
1.50	0.08	27.93	0.00	0.00	0.00	0.00	1.00
1.60	0.08	28.02	0.00	0.00	0.00	0.00	1.00
1.70	0.09	28.09	0.00	0.00	0.00	0.00	1.00
1.80	0.09	28.19	0.00	0.00	0.00	0.00	1.00
1.90	0.09	28.25	0.00	0.00	0.00	0.00	1.00
2.00	0.10	28.34	0.00	0.00	0.00	0.00	1.00

Table 195: Put option prices for October Nino 3.4 SST conditioned on IRI ensemble forecasts released in January

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.51	24.78	0.00	0.00	0.53	1.00	1.00
-1.90	0.49	24.88	0.00	0.00	0.47	1.00	1.00
-1.80	0.48	24.98	0.00	0.00	0.44	1.00	1.00
-1.70	0.47	25.08	0.00	0.00	0.38	1.00	1.00
-1.60	0.45	25.18	0.00	0.00	0.32	1.00	1.00
-1.50	0.43	25.28	0.00	0.00	0.28	1.00	1.00
-1.40	0.41	25.38	0.00	0.00	0.23	1.00	1.00
-1.30	0.39	25.47	0.00	0.00	0.18	0.95	1.00
-1.20	0.37	25.57	0.00	0.00	0.12	0.85	1.00
-1.10	0.34	25.67	0.00	0.00	0.07	0.75	1.00
-1.00	0.31	25.77	0.00	0.00	0.02	0.65	1.00
-0.90	0.28	25.87	0.00	0.00	0.00	0.56	1.00
-0.80	0.25	25.96	0.00	0.00	0.00	0.47	1.00
-0.70	0.22	26.07	0.00	0.00	0.00	0.38	1.00
-0.60	0.19	26.16	0.00	0.00	0.00	0.29	1.00
-0.50	0.16	26.26	0.00	0.00	0.00	0.21	1.00
-0.40	0.13	26.36	0.00	0.00	0.00	0.12	1.00
-0.30	0.10	26.46	0.00	0.00	0.00	0.04	0.89
-0.20	0.08	26.56	0.00	0.00	0.00	0.00	0.78
-0.10	0.06	26.66	0.00	0.00	0.00	0.00	0.66
0.00	0.05	26.76	0.00	0.00	0.00	0.00	0.59
0.10	0.04	26.85	0.00	0.00	0.00	0.00	0.54
0.20	0.04	26.95	0.00	0.00	0.00	0.00	0.52
0.30	0.04	27.05	0.00	0.00	0.00	0.00	0.51
0.40	0.04	27.15	0.00	0.00	0.00	0.00	0.54
0.50	0.04	27.25	0.00	0.00	0.00	0.00	0.58
0.60	0.04	27.35	0.00	0.00	0.00	0.00	0.62
0.70	0.05	27.45	0.00	0.00	0.00	0.00	0.68
0.80	0.05	27.55	0.00	0.00	0.00	0.00	0.76
0.90	0.06	27.65	0.00	0.00	0.00	0.00	0.84
1.00	0.06	27.74	0.00	0.00	0.00	0.00	0.94
1.10	0.07	27.85	0.00	0.00	0.00	0.00	1.00
1.20	0.08	27.94	0.00	0.00	0.00	0.00	1.00
1.30	0.08	28.05	0.00	0.00	0.00	0.00	1.00
1.40	0.09	28.13	0.00	0.00	0.00	0.00	1.00
1.50	0.09	28.24	0.00	0.00	0.00	0.00	1.00
1.60	0.09	28.34	0.00	0.00	0.00	0.00	1.00
1.70	0.10	28.43	0.00	0.00	0.00	0.00	1.00
1.80	0.10	28.54	0.00	0.00	0.00	0.00	1.00
1.90	0.11	28.64	0.00	0.00	0.00	0.00	1.00
2.00	0.11	28.74	0.00	0.00	0.00	0.00	1.00

Table 196: Put option prices for October Nino 3.4 SST conditioned on IRI ensemble forecasts released in December

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.25	27.36	0.00	0.00	0.00	0.50	1.00
-1.90	0.25	27.34	0.00	0.00	0.00	0.45	1.00
-1.80	0.24	27.31	0.00	0.00	0.00	0.41	1.00
-1.70	0.23	27.28	0.00	0.00	0.00	0.37	1.00
-1.60	0.22	27.25	0.00	0.00	0.00	0.33	1.00
-1.50	0.21	27.23	0.00	0.00	0.00	0.28	1.00
-1.40	0.20	27.20	0.00	0.00	0.00	0.24	1.00
-1.30	0.19	27.17	0.00	0.00	0.00	0.21	1.00
-1.20	0.18	27.15	0.00	0.00	0.00	0.15	1.00
-1.10	0.17	27.12	0.00	0.00	0.00	0.12	1.00
-1.00	0.16	27.10	0.00	0.00	0.00	0.08	1.00
-0.90	0.14	27.06	0.00	0.00	0.00	0.04	1.00
-0.80	0.13	27.05	0.00	0.00	0.00	0.00	1.00
-0.70	0.12	27.01	0.00	0.00	0.00	0.00	1.00
-0.60	0.10	26.99	0.00	0.00	0.00	0.00	1.00
-0.50	0.09	26.97	0.00	0.00	0.00	0.00	0.96
-0.40	0.08	26.93	0.00	0.00	0.00	0.00	0.87
-0.30	0.07	26.90	0.00	0.00	0.00	0.00	0.78
-0.20	0.06	26.87	0.00	0.00	0.00	0.00	0.68
-0.10	0.05	26.85	0.00	0.00	0.00	0.00	0.63
0.00	0.05	26.81	0.00	0.00	0.00	0.00	0.61
0.10	0.05	26.78	0.00	0.00	0.00	0.00	0.60
0.20	0.06	26.77	0.00	0.00	0.00	0.00	0.63
0.30	0.06	26.75	0.00	0.00	0.00	0.00	0.69
0.40	0.08	26.71	0.00	0.00	0.00	0.00	0.79
0.50	0.09	26.69	0.00	0.00	0.00	0.00	0.91
0.60	0.11	26.65	0.00	0.00	0.00	0.02	1.00
0.70	0.13	26.63	0.00	0.00	0.00	0.07	1.00
0.80	0.15	26.61	0.00	0.00	0.00	0.12	1.00
0.90	0.17	26.58	0.00	0.00	0.00	0.19	1.00
1.00	0.19	26.55	0.00	0.00	0.00	0.26	1.00
1.10	0.21	26.52	0.00	0.00	0.00	0.32	1.00
1.20	0.23	26.49	0.00	0.00	0.00	0.38	1.00
1.30	0.25	26.47	0.00	0.00	0.00	0.46	1.00
1.40	0.26	26.44	0.00	0.00	0.00	0.52	1.00
1.50	0.28	26.42	0.00	0.00	0.00	0.59	1.00
1.60	0.29	26.38	0.00	0.00	0.00	0.65	1.00
1.70	0.30	26.36	0.00	0.00	0.00	0.72	1.00
1.80	0.31	26.33	0.00	0.00	0.00	0.80	1.00
1.90	0.33	26.30	0.00	0.00	0.00	0.86	1.00
2.00	0.33	26.28	0.00	0.00	0.00	0.93	1.00

Appendix N: November Pricing

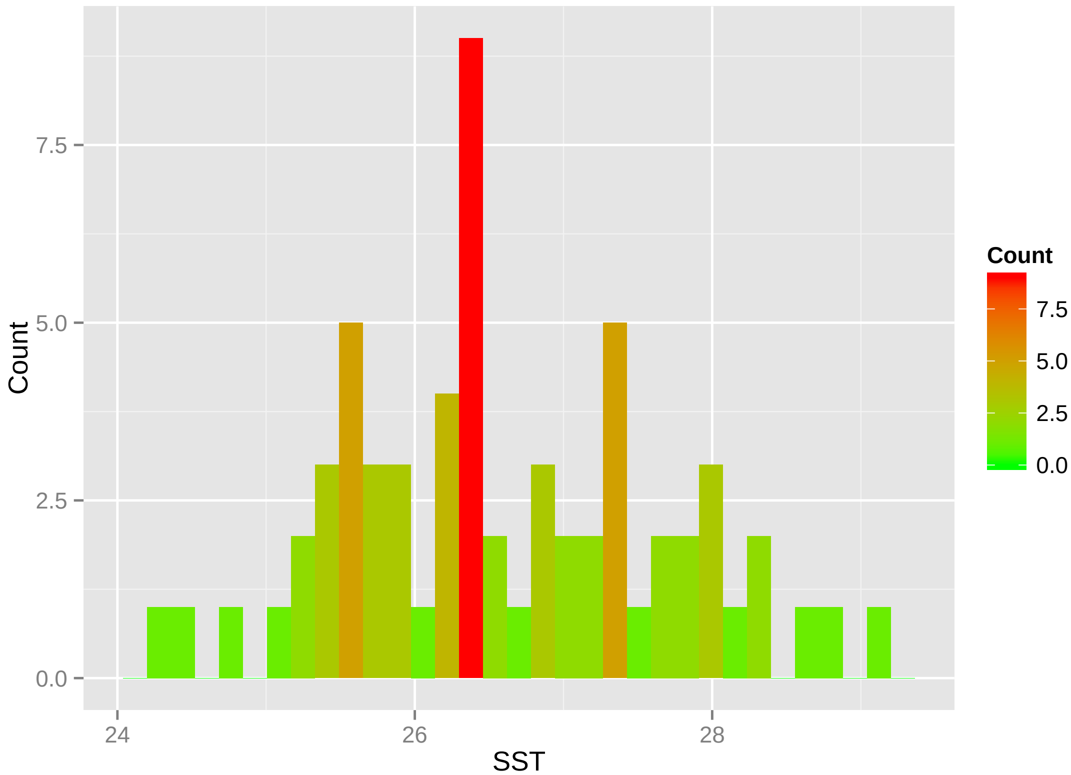


Figure 103: Histogram of November SST for Niño 3.4 ERSST.3b

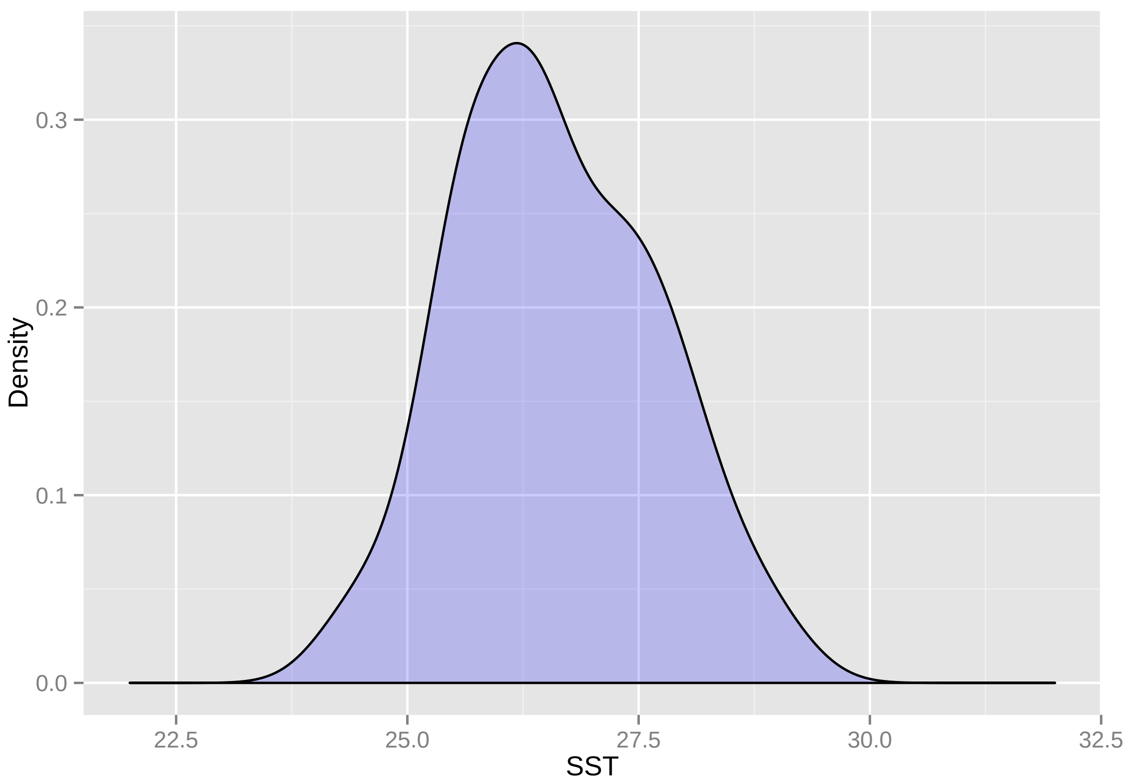


Figure 104: Kernel density estimate of November SST for Niño 3.4 ERSST.3b

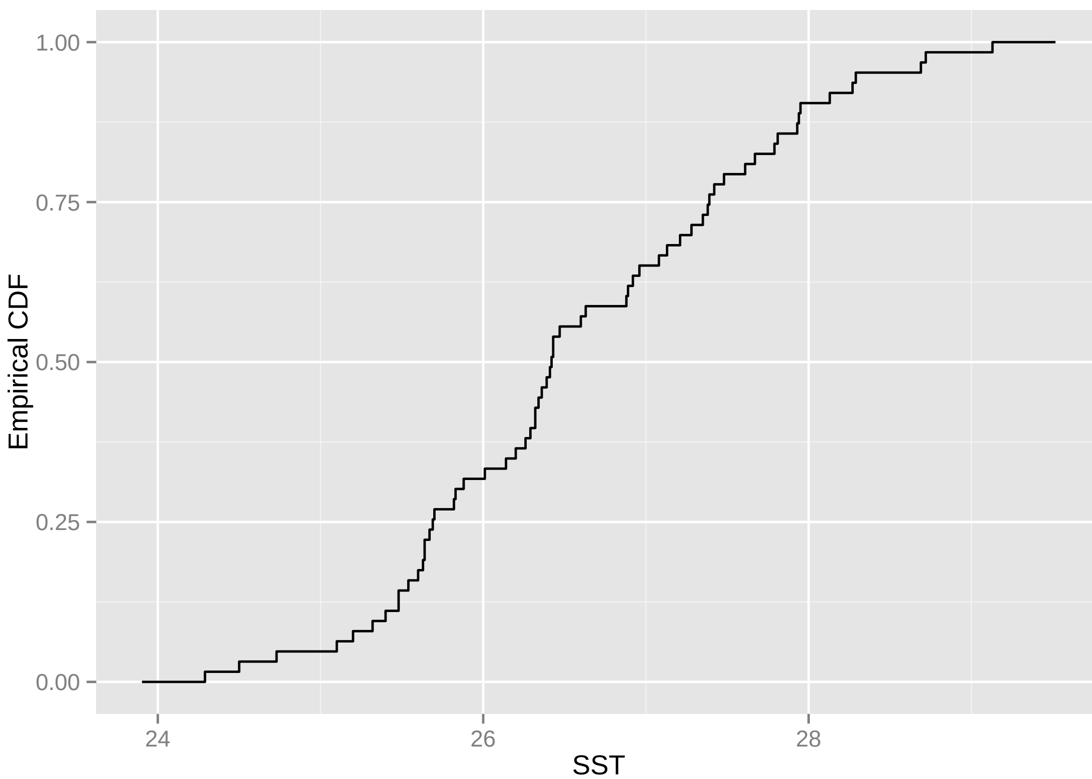


Figure 105: ECDF of November SST for Niño 3.4 ERSST.3b

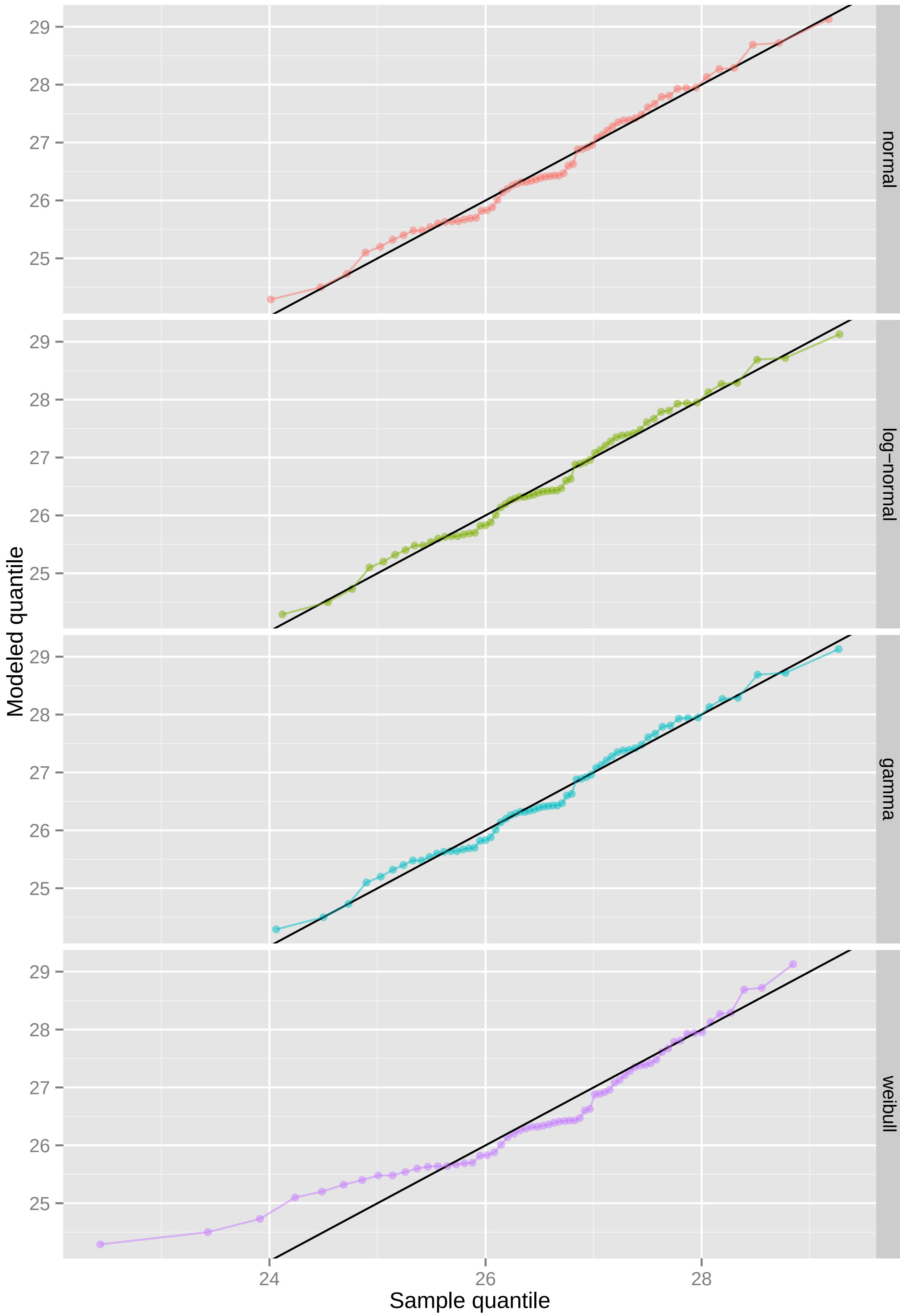


Figure 106: QQ plots of November SST for Niño 3.4 ERSST.3b compared to samples from various distributions (n=2 million)

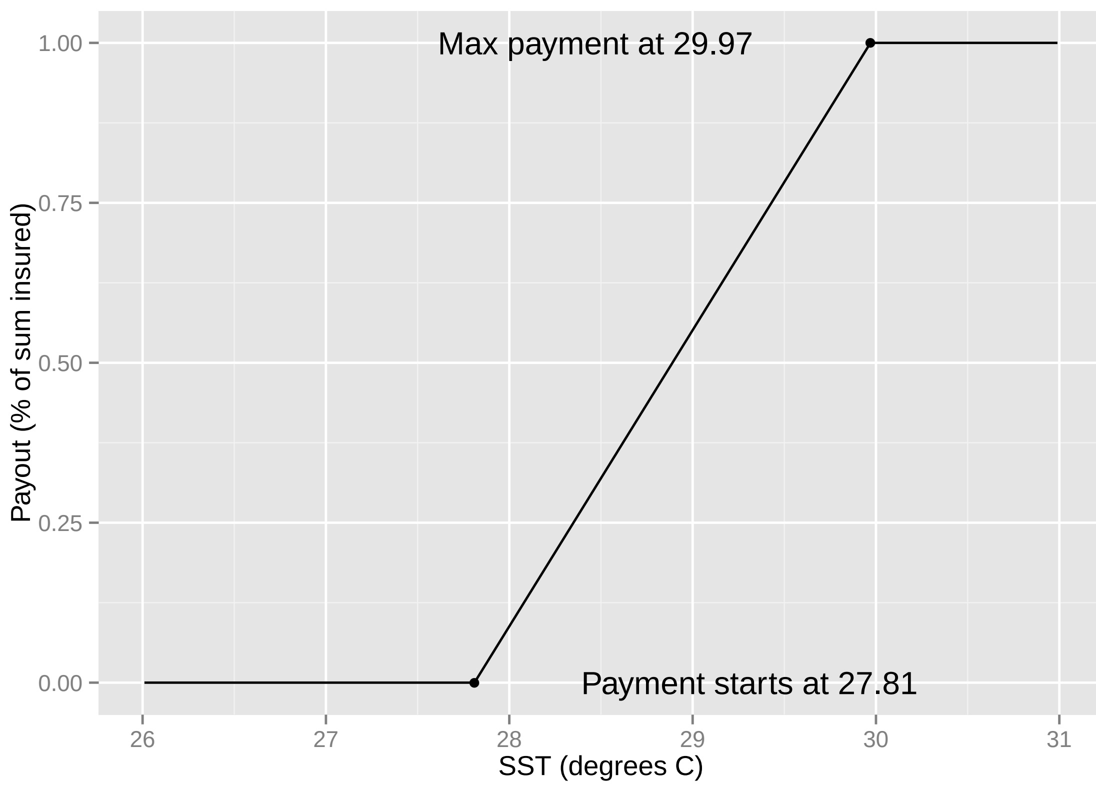


Figure 107: Payout function for call option on November SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations above the baseline

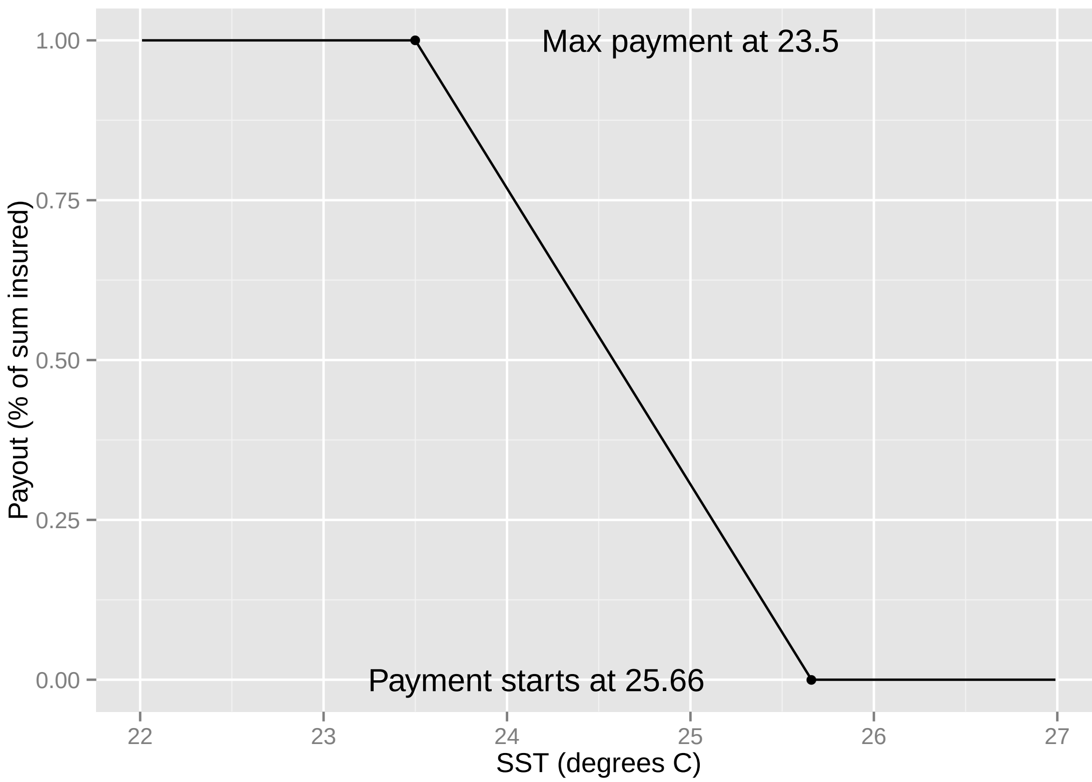


Figure 108: Payout function for put option on November SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

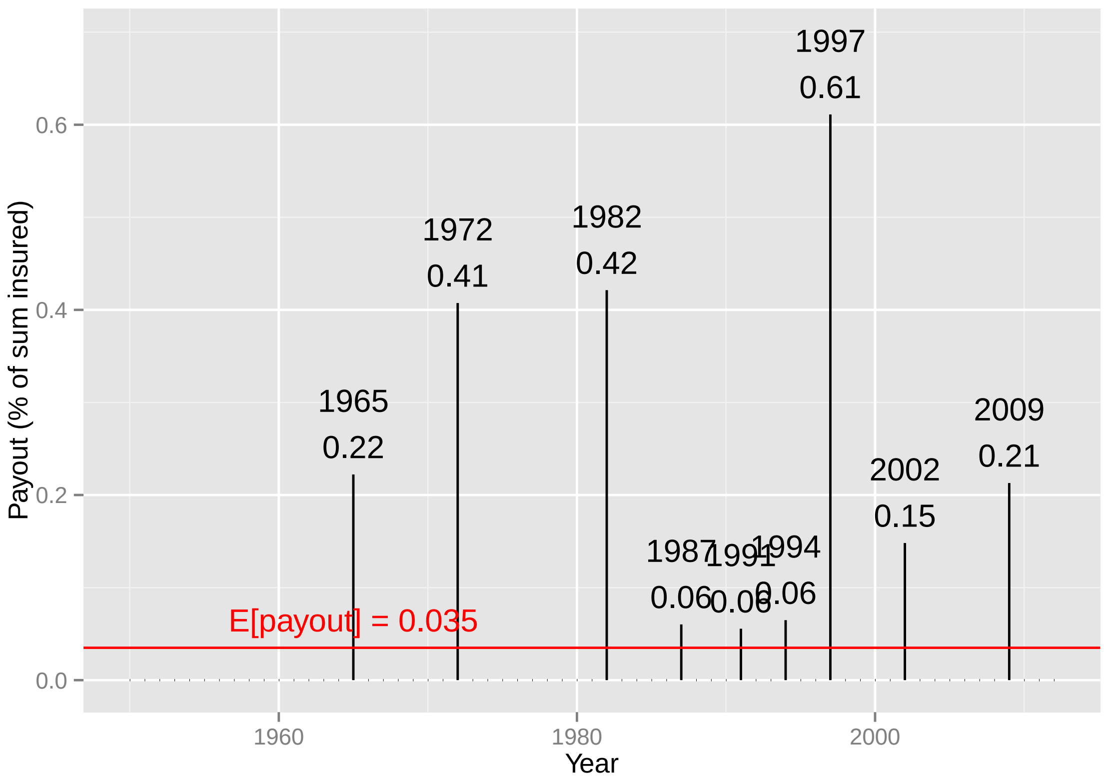


Figure 109: Historical burn on call option for November SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations above the baseline

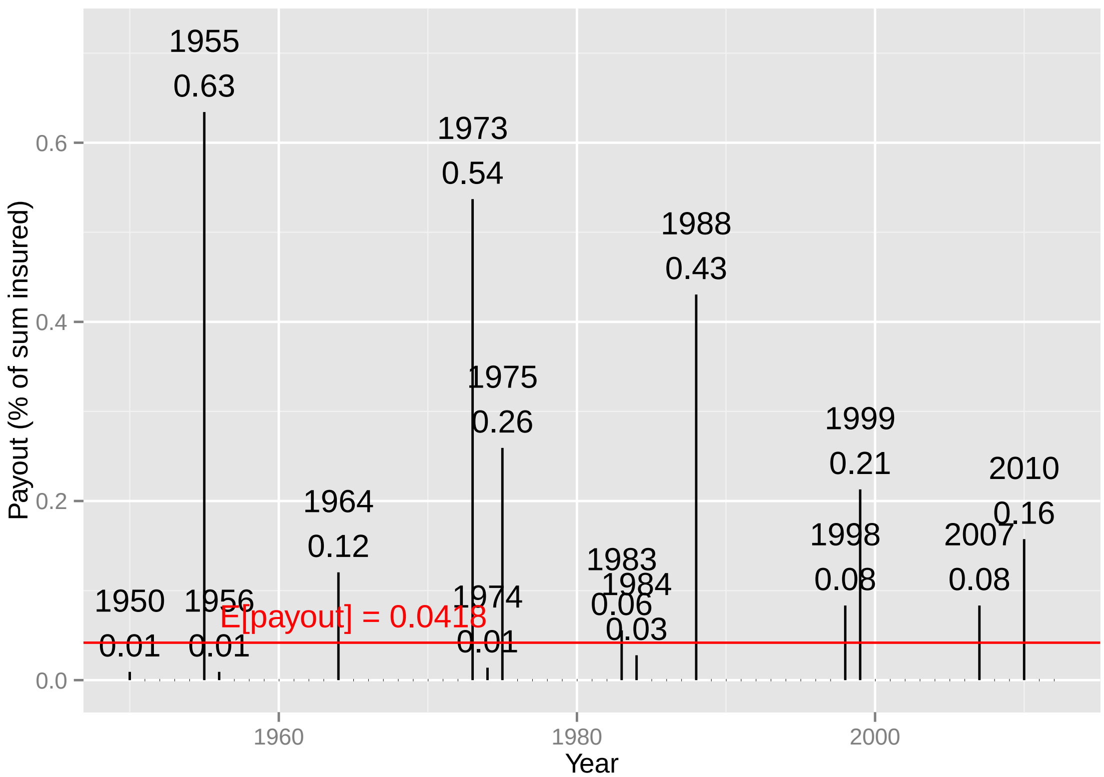


Figure 110: Historical burn on put option on November SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

Table 197: Bayesian regression linking November Niño 3.4 SST anomalies to average of relevant IRI ensemble forecasts

	mean	sd	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q	n_eff	Rhat
September forecast average covering November Niño 3.4 SST anomalies									
α	-0.20	0.20	-0.50	-0.30	-0.20	-0.10	0.20	93264	1
β	1.20	0.20	0.80	1.00	1.20	1.30	1.50	90244	1
σ_y^2	0.30	0.20	0.10	0.20	0.20	0.30	0.70	57528	1
August forecast average covering November Niño 3.4 SST anomalies									
α	-0.20	0.20	-0.60	-0.30	-0.20	-0.10	0.20	90688	1
β	1.20	0.30	0.70	1.10	1.20	1.40	1.70	88742	1
σ_y^2	0.40	0.20	0.10	0.20	0.30	0.40	0.90	57467	1
July forecast average covering November Niño 3.4 SST anomalies									
α	-0.20	0.20	-0.70	-0.40	-0.20	-0.10	0.30	92764	1
β	1.40	0.40	0.70	1.10	1.40	1.60	2.10	88264	1
σ_y^2	0.50	0.40	0.20	0.30	0.40	0.60	1.50	49508	1
June forecast average covering November Niño 3.4 SST anomalies									
α	-0.20	0.20	-0.60	-0.30	-0.20	0.00	0.30	92820	1
β	1.60	0.40	0.70	1.30	1.60	1.80	2.40	89568	1
σ_y^2	0.60	0.40	0.20	0.40	0.50	0.70	1.50	60245	1
May forecast average covering November Niño 3.4 SST anomalies									
α	-0.20	0.30	-0.70	-0.30	-0.20	0.00	0.40	94289	1
β	1.70	0.70	0.40	1.30	1.70	2.20	3.10	89189	1
σ_y^2	0.80	0.50	0.30	0.50	0.70	1.00	2.20	58552	1
April forecast average covering November Niño 3.4 SST anomalies									
α	-0.20	0.30	-0.80	-0.40	-0.20	0.00	0.40	90398	1
β	2.00	0.80	0.30	1.40	2.00	2.50	3.60	88003	1
σ_y^2	0.90	0.60	0.30	0.60	0.80	1.10	2.30	58343	1
March forecast average covering November Niño 3.4 SST anomalies									
α	0.00	0.30	-0.60	-0.20	0.00	0.20	0.60	98797	1
β	1.90	1.10	-0.30	1.20	1.90	2.60	4.00	94489	1
σ_y^2	1.10	0.70	0.40	0.70	1.00	1.30	2.90	59508	1
February forecast average covering November Niño 3.4 SST anomalies									
α	-0.20	0.40	-0.90	-0.40	-0.20	0.00	0.60	97432	1
β	0.60	1.50	-2.40	-0.30	0.60	1.50	3.60	87263	1
σ_y^2	1.50	1.10	0.50	0.80	1.20	1.80	4.30	55339	1
January forecast average covering November Niño 3.4 SST anomalies									
α	-0.10	0.40	-0.90	-0.40	-0.10	0.20	0.70	101125	1
β	0.50	2.30	-4.20	-1.00	0.50	1.90	5.10	89721	1
σ_y^2	1.80	1.40	0.60	1.00	1.40	2.10	5.10	57556	1

Table 198: Call option prices for November Nino 3.4 SST conditioned on IRI ensemble forecasts released in September

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	24.27	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	24.39	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.50	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.62	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.73	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.85	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	24.96	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	25.08	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	25.20	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.31	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.43	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.54	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.66	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.77	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.88	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	26.00	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.12	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.24	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.35	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	26.46	0.00	0.00	0.00	0.00	0.00
0.00	0.00	26.58	0.00	0.00	0.00	0.00	0.00
0.10	0.00	26.69	0.00	0.00	0.00	0.00	0.00
0.20	0.00	26.81	0.00	0.00	0.00	0.00	0.03
0.30	0.01	26.92	0.00	0.00	0.00	0.00	0.09
0.40	0.01	27.04	0.00	0.00	0.00	0.00	0.14
0.50	0.01	27.15	0.00	0.00	0.00	0.00	0.20
0.60	0.02	27.27	0.00	0.00	0.00	0.00	0.25
0.70	0.03	27.38	0.00	0.00	0.00	0.00	0.30
0.80	0.04	27.50	0.00	0.00	0.00	0.02	0.36
0.90	0.06	27.62	0.00	0.00	0.00	0.07	0.42
1.00	0.08	27.73	0.00	0.00	0.00	0.12	0.48
1.10	0.11	27.85	0.00	0.00	0.02	0.18	0.54
1.20	0.14	27.96	0.00	0.00	0.07	0.24	0.59
1.30	0.18	28.08	0.00	0.00	0.12	0.29	0.66
1.40	0.22	28.20	0.00	0.01	0.18	0.35	0.72
1.50	0.26	28.31	0.00	0.06	0.23	0.40	0.78
1.60	0.30	28.42	0.00	0.11	0.28	0.46	0.83
1.70	0.35	28.54	0.00	0.16	0.34	0.51	0.90
1.80	0.40	28.66	0.00	0.22	0.39	0.57	0.96
1.90	0.45	28.77	0.00	0.27	0.44	0.62	1.00
2.00	0.50	28.89	0.00	0.32	0.50	0.68	1.00

Table 199: Call option prices for November Nino 3.4 SST conditioned on IRI ensemble forecasts released in August

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	24.05	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	24.17	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.30	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.43	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.55	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.67	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	24.79	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	24.92	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	25.04	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.16	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.28	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.41	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.53	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.65	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.78	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	25.90	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.02	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.15	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.27	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	26.40	0.00	0.00	0.00	0.00	0.00
0.00	0.00	26.52	0.00	0.00	0.00	0.00	0.00
0.10	0.01	26.64	0.00	0.00	0.00	0.00	0.05
0.20	0.01	26.76	0.00	0.00	0.00	0.00	0.10
0.30	0.01	26.89	0.00	0.00	0.00	0.00	0.16
0.40	0.02	27.01	0.00	0.00	0.00	0.00	0.22
0.50	0.02	27.14	0.00	0.00	0.00	0.00	0.28
0.60	0.03	27.26	0.00	0.00	0.00	0.00	0.34
0.70	0.04	27.38	0.00	0.00	0.00	0.00	0.39
0.80	0.06	27.50	0.00	0.00	0.00	0.04	0.46
0.90	0.08	27.63	0.00	0.00	0.00	0.11	0.52
1.00	0.10	27.75	0.00	0.00	0.00	0.16	0.58
1.10	0.14	27.88	0.00	0.00	0.03	0.22	0.65
1.20	0.17	28.00	0.00	0.00	0.09	0.28	0.72
1.30	0.21	28.12	0.00	0.00	0.14	0.34	0.79
1.40	0.25	28.24	0.00	0.00	0.20	0.40	0.84
1.50	0.29	28.37	0.00	0.05	0.26	0.46	0.91
1.60	0.34	28.49	0.00	0.11	0.32	0.52	0.99
1.70	0.39	28.62	0.00	0.17	0.37	0.58	1.00
1.80	0.44	28.74	0.00	0.21	0.43	0.65	1.00
1.90	0.49	28.86	0.00	0.27	0.49	0.71	1.00
2.00	0.54	28.99	0.00	0.32	0.54	0.77	1.00

Table 200: Call option prices for November Nino 3.4 SST conditioned on IRI ensemble forecasts released in July

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	23.80	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	23.94	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.07	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.20	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.35	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.48	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	24.63	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	24.76	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	24.89	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.04	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.16	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.29	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.44	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.58	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.70	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	25.85	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	25.99	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.12	0.00	0.00	0.00	0.00	0.00
-0.20	0.01	26.25	0.00	0.00	0.00	0.00	0.00
-0.10	0.01	26.39	0.00	0.00	0.00	0.00	0.06
0.00	0.01	26.52	0.00	0.00	0.00	0.00	0.11
0.10	0.01	26.66	0.00	0.00	0.00	0.00	0.18
0.20	0.02	26.80	0.00	0.00	0.00	0.00	0.24
0.30	0.02	26.93	0.00	0.00	0.00	0.00	0.30
0.40	0.03	27.07	0.00	0.00	0.00	0.00	0.37
0.50	0.04	27.21	0.00	0.00	0.00	0.00	0.45
0.60	0.06	27.35	0.00	0.00	0.00	0.01	0.51
0.70	0.08	27.48	0.00	0.00	0.00	0.07	0.58
0.80	0.10	27.61	0.00	0.00	0.00	0.13	0.65
0.90	0.13	27.75	0.00	0.00	0.00	0.20	0.73
1.00	0.16	27.89	0.00	0.00	0.04	0.27	0.80
1.10	0.20	28.03	0.00	0.00	0.10	0.34	0.88
1.20	0.24	28.17	0.00	0.00	0.16	0.41	0.96
1.30	0.29	28.30	0.00	0.00	0.23	0.47	1.00
1.40	0.34	28.44	0.00	0.04	0.29	0.54	1.00
1.50	0.38	28.57	0.00	0.10	0.35	0.61	1.00
1.60	0.43	28.71	0.00	0.15	0.41	0.68	1.00
1.70	0.48	28.84	0.00	0.21	0.48	0.74	1.00
1.80	0.53	28.98	0.00	0.27	0.54	0.81	1.00
1.90	0.58	29.12	0.00	0.32	0.61	0.88	1.00
2.00	0.62	29.25	0.00	0.38	0.67	0.95	1.00

Table 201: Call option prices for November Nino 3.4 SST conditioned on IRI ensemble forecasts released in June

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	23.45	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	23.61	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	23.77	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	23.93	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.08	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.24	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	24.40	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	24.56	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	24.70	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	24.86	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.02	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.18	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.33	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.49	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.65	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	25.81	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	25.96	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.12	0.00	0.00	0.00	0.00	0.00
-0.20	0.01	26.27	0.00	0.00	0.00	0.00	0.04
-0.10	0.01	26.43	0.00	0.00	0.00	0.00	0.09
0.00	0.01	26.58	0.00	0.00	0.00	0.00	0.15
0.10	0.02	26.75	0.00	0.00	0.00	0.00	0.23
0.20	0.02	26.89	0.00	0.00	0.00	0.00	0.29
0.30	0.03	27.06	0.00	0.00	0.00	0.00	0.38
0.40	0.05	27.22	0.00	0.00	0.00	0.00	0.46
0.50	0.06	27.37	0.00	0.00	0.00	0.02	0.53
0.60	0.09	27.52	0.00	0.00	0.00	0.10	0.61
0.70	0.12	27.68	0.00	0.00	0.00	0.18	0.69
0.80	0.15	27.83	0.00	0.00	0.01	0.25	0.78
0.90	0.19	27.99	0.00	0.00	0.08	0.33	0.86
1.00	0.24	28.15	0.00	0.00	0.15	0.41	0.97
1.10	0.29	28.30	0.00	0.00	0.23	0.48	1.00
1.20	0.35	28.46	0.00	0.04	0.30	0.56	1.00
1.30	0.40	28.62	0.00	0.11	0.37	0.64	1.00
1.40	0.46	28.77	0.00	0.18	0.45	0.72	1.00
1.50	0.51	28.93	0.00	0.24	0.52	0.80	1.00
1.60	0.57	29.09	0.00	0.30	0.59	0.88	1.00
1.70	0.62	29.25	0.00	0.37	0.66	0.96	1.00
1.80	0.66	29.40	0.00	0.43	0.73	1.00	1.00
1.90	0.71	29.55	0.00	0.49	0.81	1.00	1.00
2.00	0.75	29.72	0.00	0.56	0.88	1.00	1.00

Table 202: Call option prices for November Nino 3.4 SST conditioned on IRI ensemble forecasts released in May

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	23.12	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	23.30	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	23.46	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	23.65	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	23.82	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	23.99	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	24.16	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	24.33	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	24.50	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	24.68	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	24.85	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.02	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.20	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.38	0.00	0.00	0.00	0.00	0.00
-0.60	0.01	25.54	0.00	0.00	0.00	0.00	0.00
-0.50	0.01	25.72	0.00	0.00	0.00	0.00	0.02
-0.40	0.01	25.89	0.00	0.00	0.00	0.00	0.06
-0.30	0.01	26.06	0.00	0.00	0.00	0.00	0.12
-0.20	0.01	26.24	0.00	0.00	0.00	0.00	0.19
-0.10	0.02	26.41	0.00	0.00	0.00	0.00	0.24
0.00	0.02	26.59	0.00	0.00	0.00	0.00	0.32
0.10	0.03	26.76	0.00	0.00	0.00	0.00	0.40
0.20	0.04	26.94	0.00	0.00	0.00	0.00	0.50
0.30	0.06	27.11	0.00	0.00	0.00	0.00	0.57
0.40	0.08	27.28	0.00	0.00	0.00	0.03	0.66
0.50	0.10	27.45	0.00	0.00	0.00	0.12	0.74
0.60	0.14	27.62	0.00	0.00	0.00	0.20	0.85
0.70	0.18	27.79	0.00	0.00	0.00	0.29	0.94
0.80	0.22	27.97	0.00	0.00	0.07	0.38	1.00
0.90	0.27	28.14	0.00	0.00	0.15	0.47	1.00
1.00	0.32	28.32	0.00	0.00	0.24	0.56	1.00
1.10	0.38	28.50	0.00	0.00	0.31	0.65	1.00
1.20	0.43	28.67	0.00	0.05	0.40	0.74	1.00
1.30	0.48	28.84	0.00	0.12	0.47	0.83	1.00
1.40	0.53	29.01	0.00	0.18	0.56	0.93	1.00
1.50	0.58	29.18	0.00	0.25	0.64	1.00	1.00
1.60	0.63	29.36	0.00	0.32	0.72	1.00	1.00
1.70	0.66	29.52	0.00	0.38	0.79	1.00	1.00
1.80	0.70	29.70	0.00	0.44	0.88	1.00	1.00
1.90	0.74	29.88	0.00	0.51	0.96	1.00	1.00
2.00	0.76	30.05	0.00	0.58	1.00	1.00	1.00

Table 203: Call option prices for November Nino 3.4 SST conditioned on IRI ensemble forecasts released in April

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	22.60	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	22.80	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	22.99	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	23.20	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	23.38	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	23.58	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	23.77	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	23.98	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	24.17	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	24.36	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	24.57	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	24.76	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	24.96	0.00	0.00	0.00	0.00	0.00
-0.70	0.01	25.16	0.00	0.00	0.00	0.00	0.00
-0.60	0.01	25.34	0.00	0.00	0.00	0.00	0.00
-0.50	0.01	25.55	0.00	0.00	0.00	0.00	0.00
-0.40	0.01	25.75	0.00	0.00	0.00	0.00	0.06
-0.30	0.01	25.94	0.00	0.00	0.00	0.00	0.10
-0.20	0.01	26.14	0.00	0.00	0.00	0.00	0.16
-0.10	0.02	26.34	0.00	0.00	0.00	0.00	0.24
0.00	0.02	26.53	0.00	0.00	0.00	0.00	0.32
0.10	0.03	26.73	0.00	0.00	0.00	0.00	0.40
0.20	0.04	26.92	0.00	0.00	0.00	0.00	0.51
0.30	0.06	27.12	0.00	0.00	0.00	0.00	0.60
0.40	0.09	27.32	0.00	0.00	0.00	0.06	0.70
0.50	0.12	27.52	0.00	0.00	0.00	0.16	0.81
0.60	0.16	27.71	0.00	0.00	0.00	0.26	0.92
0.70	0.21	27.90	0.00	0.00	0.04	0.36	1.00
0.80	0.26	28.11	0.00	0.00	0.14	0.46	1.00
0.90	0.32	28.31	0.00	0.00	0.23	0.57	1.00
1.00	0.38	28.49	0.00	0.00	0.32	0.67	1.00
1.10	0.45	28.70	0.00	0.05	0.41	0.78	1.00
1.20	0.50	28.89	0.00	0.12	0.50	0.88	1.00
1.30	0.55	29.08	0.00	0.19	0.59	0.99	1.00
1.40	0.61	29.28	0.00	0.27	0.68	1.00	1.00
1.50	0.65	29.49	0.00	0.35	0.78	1.00	1.00
1.60	0.69	29.68	0.00	0.41	0.87	1.00	1.00
1.70	0.72	29.87	0.00	0.49	0.96	1.00	1.00
1.80	0.76	30.07	0.00	0.56	1.00	1.00	1.00
1.90	0.78	30.26	0.00	0.63	1.00	1.00	1.00
2.00	0.80	30.46	0.00	0.70	1.00	1.00	1.00

Table 204: Call option prices for November Nino 3.4 SST conditioned on IRI ensemble forecasts released in March

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.01	22.95	0.00	0.00	0.00	0.00	0.05
-1.90	0.01	23.12	0.00	0.00	0.00	0.00	0.06
-1.80	0.01	23.32	0.00	0.00	0.00	0.00	0.06
-1.70	0.01	23.51	0.00	0.00	0.00	0.00	0.06
-1.60	0.01	23.69	0.00	0.00	0.00	0.00	0.04
-1.50	0.01	23.88	0.00	0.00	0.00	0.00	0.06
-1.40	0.01	24.06	0.00	0.00	0.00	0.00	0.05
-1.30	0.01	24.26	0.00	0.00	0.00	0.00	0.07
-1.20	0.01	24.44	0.00	0.00	0.00	0.00	0.08
-1.10	0.01	24.64	0.00	0.00	0.00	0.00	0.10
-1.00	0.01	24.82	0.00	0.00	0.00	0.00	0.09
-0.90	0.01	25.00	0.00	0.00	0.00	0.00	0.12
-0.80	0.01	25.20	0.00	0.00	0.00	0.00	0.12
-0.70	0.01	25.39	0.00	0.00	0.00	0.00	0.15
-0.60	0.01	25.58	0.00	0.00	0.00	0.00	0.19
-0.50	0.02	25.76	0.00	0.00	0.00	0.00	0.23
-0.40	0.02	25.96	0.00	0.00	0.00	0.00	0.27
-0.30	0.02	26.14	0.00	0.00	0.00	0.00	0.31
-0.20	0.02	26.32	0.00	0.00	0.00	0.00	0.37
-0.10	0.03	26.51	0.00	0.00	0.00	0.00	0.44
0.00	0.04	26.70	0.00	0.00	0.00	0.00	0.51
0.10	0.05	26.89	0.00	0.00	0.00	0.00	0.59
0.20	0.07	27.08	0.00	0.00	0.00	0.00	0.69
0.30	0.10	27.26	0.00	0.00	0.00	0.07	0.79
0.40	0.13	27.45	0.00	0.00	0.00	0.17	0.91
0.50	0.17	27.64	0.00	0.00	0.00	0.27	1.00
0.60	0.21	27.82	0.00	0.00	0.00	0.37	1.00
0.70	0.26	28.01	0.00	0.00	0.09	0.47	1.00
0.80	0.32	28.21	0.00	0.00	0.18	0.58	1.00
0.90	0.37	28.38	0.00	0.00	0.26	0.68	1.00
1.00	0.42	28.58	0.00	0.00	0.36	0.79	1.00
1.10	0.47	28.76	0.00	0.00	0.44	0.90	1.00
1.20	0.51	28.96	0.00	0.05	0.53	1.00	1.00
1.30	0.56	29.14	0.00	0.11	0.61	1.00	1.00
1.40	0.59	29.32	0.00	0.17	0.70	1.00	1.00
1.50	0.63	29.53	0.00	0.24	0.79	1.00	1.00
1.60	0.66	29.71	0.00	0.30	0.88	1.00	1.00
1.70	0.69	29.89	0.00	0.36	0.96	1.00	1.00
1.80	0.71	30.09	0.00	0.42	1.00	1.00	1.00
1.90	0.73	30.27	0.00	0.48	1.00	1.00	1.00
2.00	0.75	30.45	0.00	0.54	1.00	1.00	1.00

Table 205: Call option prices for November Nino 3.4 SST conditioned on IRI ensemble forecasts released in February

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.13	25.29	0.00	0.00	0.00	0.00	1.00
-1.90	0.12	25.34	0.00	0.00	0.00	0.00	1.00
-1.80	0.12	25.40	0.00	0.00	0.00	0.00	1.00
-1.70	0.11	25.47	0.00	0.00	0.00	0.00	1.00
-1.60	0.11	25.53	0.00	0.00	0.00	0.00	1.00
-1.50	0.10	25.60	0.00	0.00	0.00	0.00	1.00
-1.40	0.10	25.66	0.00	0.00	0.00	0.00	1.00
-1.30	0.09	25.73	0.00	0.00	0.00	0.00	1.00
-1.20	0.09	25.79	0.00	0.00	0.00	0.00	1.00
-1.10	0.08	25.86	0.00	0.00	0.00	0.00	1.00
-1.00	0.07	25.92	0.00	0.00	0.00	0.00	1.00
-0.90	0.07	25.98	0.00	0.00	0.00	0.00	0.95
-0.80	0.06	26.04	0.00	0.00	0.00	0.00	0.85
-0.70	0.06	26.11	0.00	0.00	0.00	0.00	0.80
-0.60	0.06	26.17	0.00	0.00	0.00	0.00	0.77
-0.50	0.05	26.23	0.00	0.00	0.00	0.00	0.66
-0.40	0.05	26.30	0.00	0.00	0.00	0.00	0.64
-0.30	0.05	26.36	0.00	0.00	0.00	0.00	0.60
-0.20	0.05	26.42	0.00	0.00	0.00	0.00	0.61
-0.10	0.05	26.51	0.00	0.00	0.00	0.00	0.60
0.00	0.05	26.55	0.00	0.00	0.00	0.00	0.60
0.10	0.05	26.62	0.00	0.00	0.00	0.00	0.65
0.20	0.06	26.68	0.00	0.00	0.00	0.00	0.69
0.30	0.07	26.75	0.00	0.00	0.00	0.00	0.74
0.40	0.08	26.81	0.00	0.00	0.00	0.00	0.82
0.50	0.09	26.86	0.00	0.00	0.00	0.00	0.90
0.60	0.10	26.92	0.00	0.00	0.00	0.01	0.98
0.70	0.12	27.00	0.00	0.00	0.00	0.07	1.00
0.80	0.14	27.06	0.00	0.00	0.00	0.13	1.00
0.90	0.16	27.12	0.00	0.00	0.00	0.19	1.00
1.00	0.18	27.18	0.00	0.00	0.00	0.23	1.00
1.10	0.20	27.24	0.00	0.00	0.00	0.30	1.00
1.20	0.22	27.31	0.00	0.00	0.00	0.37	1.00
1.30	0.24	27.38	0.00	0.00	0.00	0.44	1.00
1.40	0.26	27.43	0.00	0.00	0.00	0.49	1.00
1.50	0.28	27.51	0.00	0.00	0.00	0.56	1.00
1.60	0.30	27.57	0.00	0.00	0.00	0.63	1.00
1.70	0.31	27.63	0.00	0.00	0.00	0.69	1.00
1.80	0.33	27.70	0.00	0.00	0.00	0.76	1.00
1.90	0.34	27.76	0.00	0.00	0.00	0.83	1.00
2.00	0.36	27.82	0.00	0.00	0.01	0.90	1.00

Table 206: Call option prices for November Nino 3.4 SST conditioned on IRI ensemble forecasts released in January

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.24	25.75	0.00	0.00	0.00	0.44	1.00
-1.90	0.24	25.78	0.00	0.00	0.00	0.39	1.00
-1.80	0.23	25.84	0.00	0.00	0.00	0.35	1.00
-1.70	0.22	25.88	0.00	0.00	0.00	0.32	1.00
-1.60	0.21	25.92	0.00	0.00	0.00	0.27	1.00
-1.50	0.21	25.97	0.00	0.00	0.00	0.23	1.00
-1.40	0.20	26.02	0.00	0.00	0.00	0.19	1.00
-1.30	0.19	26.06	0.00	0.00	0.00	0.14	1.00
-1.20	0.17	26.10	0.00	0.00	0.00	0.10	1.00
-1.10	0.16	26.14	0.00	0.00	0.00	0.06	1.00
-1.00	0.15	26.20	0.00	0.00	0.00	0.04	1.00
-0.90	0.14	26.24	0.00	0.00	0.00	0.00	1.00
-0.80	0.13	26.29	0.00	0.00	0.00	0.00	1.00
-0.70	0.12	26.32	0.00	0.00	0.00	0.00	1.00
-0.60	0.11	26.38	0.00	0.00	0.00	0.00	1.00
-0.50	0.09	26.43	0.00	0.00	0.00	0.00	1.00
-0.40	0.08	26.47	0.00	0.00	0.00	0.00	0.97
-0.30	0.08	26.51	0.00	0.00	0.00	0.00	0.88
-0.20	0.07	26.55	0.00	0.00	0.00	0.00	0.80
-0.10	0.06	26.60	0.00	0.00	0.00	0.00	0.77
0.00	0.06	26.64	0.00	0.00	0.00	0.00	0.75
0.10	0.07	26.69	0.00	0.00	0.00	0.00	0.78
0.20	0.08	26.72	0.00	0.00	0.00	0.00	0.84
0.30	0.09	26.78	0.00	0.00	0.00	0.00	0.94
0.40	0.10	26.82	0.00	0.00	0.00	0.00	1.00
0.50	0.12	26.87	0.00	0.00	0.00	0.05	1.00
0.60	0.15	26.91	0.00	0.00	0.00	0.12	1.00
0.70	0.17	26.96	0.00	0.00	0.00	0.19	1.00
0.80	0.19	27.00	0.00	0.00	0.00	0.26	1.00
0.90	0.21	27.05	0.00	0.00	0.00	0.33	1.00
1.00	0.23	27.08	0.00	0.00	0.00	0.40	1.00
1.10	0.25	27.13	0.00	0.00	0.00	0.49	1.00
1.20	0.27	27.18	0.00	0.00	0.00	0.56	1.00
1.30	0.29	27.22	0.00	0.00	0.00	0.64	1.00
1.40	0.30	27.26	0.00	0.00	0.00	0.71	1.00
1.50	0.32	27.31	0.00	0.00	0.00	0.81	1.00
1.60	0.33	27.35	0.00	0.00	0.00	0.88	1.00
1.70	0.35	27.40	0.00	0.00	0.00	0.96	1.00
1.80	0.36	27.44	0.00	0.00	0.00	1.00	1.00
1.90	0.37	27.49	0.00	0.00	0.00	1.00	1.00
2.00	0.38	27.53	0.00	0.00	0.00	1.00	1.00

Table 207: Put option prices for November Nino 3.4 SST conditioned on IRI ensemble forecasts released in September

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.63	24.27	0.00	0.44	0.64	0.84	1.00
-1.90	0.58	24.39	0.00	0.39	0.59	0.78	1.00
-1.80	0.53	24.50	0.00	0.35	0.54	0.73	1.00
-1.70	0.49	24.62	0.00	0.30	0.48	0.67	1.00
-1.60	0.44	24.73	0.00	0.25	0.43	0.62	1.00
-1.50	0.39	24.85	0.00	0.20	0.38	0.56	0.96
-1.40	0.34	24.96	0.00	0.14	0.32	0.50	0.90
-1.30	0.29	25.08	0.00	0.10	0.27	0.45	0.83
-1.20	0.25	25.20	0.00	0.04	0.22	0.39	0.77
-1.10	0.21	25.31	0.00	0.00	0.16	0.33	0.70
-1.00	0.17	25.43	0.00	0.00	0.11	0.28	0.65
-0.90	0.13	25.54	0.00	0.00	0.06	0.22	0.59
-0.80	0.10	25.66	0.00	0.00	0.00	0.17	0.53
-0.70	0.08	25.77	0.00	0.00	0.00	0.11	0.48
-0.60	0.06	25.88	0.00	0.00	0.00	0.06	0.41
-0.50	0.04	26.00	0.00	0.00	0.00	0.00	0.36
-0.40	0.03	26.12	0.00	0.00	0.00	0.00	0.29
-0.30	0.02	26.24	0.00	0.00	0.00	0.00	0.23
-0.20	0.01	26.35	0.00	0.00	0.00	0.00	0.18
-0.10	0.01	26.46	0.00	0.00	0.00	0.00	0.12
0.00	0.01	26.58	0.00	0.00	0.00	0.00	0.07
0.10	0.00	26.69	0.00	0.00	0.00	0.00	0.01
0.20	0.00	26.81	0.00	0.00	0.00	0.00	0.00
0.30	0.00	26.92	0.00	0.00	0.00	0.00	0.00
0.40	0.00	27.04	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.15	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.27	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.38	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.50	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.62	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.73	0.00	0.00	0.00	0.00	0.00
1.10	0.00	27.85	0.00	0.00	0.00	0.00	0.00
1.20	0.00	27.96	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.08	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.20	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.31	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.42	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.54	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.66	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.77	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.89	0.00	0.00	0.00	0.00	0.00

Table 208: Put option prices for November Nino 3.4 SST conditioned on IRI ensemble forecasts released in August

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.69	24.05	0.00	0.50	0.74	0.99	1.00
-1.90	0.65	24.17	0.00	0.45	0.69	0.93	1.00
-1.80	0.61	24.30	0.00	0.39	0.63	0.86	1.00
-1.70	0.56	24.43	0.00	0.34	0.57	0.80	1.00
-1.60	0.51	24.55	0.00	0.29	0.51	0.74	1.00
-1.50	0.47	24.67	0.00	0.24	0.46	0.68	1.00
-1.40	0.42	24.79	0.00	0.19	0.41	0.62	1.00
-1.30	0.37	24.92	0.00	0.13	0.35	0.56	1.00
-1.20	0.32	25.04	0.00	0.08	0.29	0.50	0.96
-1.10	0.28	25.16	0.00	0.02	0.23	0.44	0.90
-1.00	0.23	25.28	0.00	0.00	0.17	0.38	0.83
-0.90	0.19	25.41	0.00	0.00	0.12	0.32	0.76
-0.80	0.15	25.53	0.00	0.00	0.06	0.25	0.69
-0.70	0.12	25.65	0.00	0.00	0.00	0.20	0.62
-0.60	0.09	25.78	0.00	0.00	0.00	0.14	0.56
-0.50	0.07	25.90	0.00	0.00	0.00	0.08	0.50
-0.40	0.05	26.02	0.00	0.00	0.00	0.02	0.44
-0.30	0.04	26.15	0.00	0.00	0.00	0.00	0.37
-0.20	0.03	26.27	0.00	0.00	0.00	0.00	0.31
-0.10	0.02	26.40	0.00	0.00	0.00	0.00	0.25
0.00	0.01	26.52	0.00	0.00	0.00	0.00	0.19
0.10	0.01	26.64	0.00	0.00	0.00	0.00	0.13
0.20	0.01	26.76	0.00	0.00	0.00	0.00	0.07
0.30	0.00	26.89	0.00	0.00	0.00	0.00	0.02
0.40	0.00	27.01	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.14	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.26	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.38	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.50	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.63	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.75	0.00	0.00	0.00	0.00	0.00
1.10	0.00	27.88	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.00	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.12	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.24	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.37	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.49	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.62	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.74	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.86	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.99	0.00	0.00	0.00	0.00	0.00

Table 209: Put option prices for November Nino 3.4 SST conditioned on IRI ensemble forecasts released in July

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.74	23.80	0.00	0.55	0.86	1.00	1.00
-1.90	0.71	23.94	0.00	0.50	0.80	1.00	1.00
-1.80	0.67	24.07	0.00	0.44	0.74	1.00	1.00
-1.70	0.63	24.20	0.00	0.39	0.67	0.96	1.00
-1.60	0.58	24.35	0.00	0.32	0.61	0.89	1.00
-1.50	0.54	24.48	0.00	0.27	0.55	0.82	1.00
-1.40	0.48	24.63	0.00	0.21	0.48	0.75	1.00
-1.30	0.44	24.76	0.00	0.16	0.42	0.68	1.00
-1.20	0.39	24.89	0.00	0.10	0.36	0.61	1.00
-1.10	0.34	25.04	0.00	0.04	0.29	0.54	1.00
-1.00	0.29	25.16	0.00	0.00	0.23	0.48	1.00
-0.90	0.25	25.29	0.00	0.00	0.17	0.41	0.96
-0.80	0.20	25.44	0.00	0.00	0.11	0.34	0.88
-0.70	0.17	25.58	0.00	0.00	0.04	0.28	0.80
-0.60	0.13	25.70	0.00	0.00	0.00	0.21	0.73
-0.50	0.10	25.85	0.00	0.00	0.00	0.14	0.65
-0.40	0.08	25.99	0.00	0.00	0.00	0.07	0.57
-0.30	0.06	26.12	0.00	0.00	0.00	0.01	0.50
-0.20	0.04	26.25	0.00	0.00	0.00	0.00	0.44
-0.10	0.03	26.39	0.00	0.00	0.00	0.00	0.36
0.00	0.02	26.52	0.00	0.00	0.00	0.00	0.30
0.10	0.02	26.66	0.00	0.00	0.00	0.00	0.24
0.20	0.01	26.80	0.00	0.00	0.00	0.00	0.19
0.30	0.01	26.93	0.00	0.00	0.00	0.00	0.11
0.40	0.01	27.07	0.00	0.00	0.00	0.00	0.06
0.50	0.00	27.21	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.35	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.48	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.61	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.75	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.89	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.03	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.17	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.30	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.44	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.57	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.71	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.84	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.98	0.00	0.00	0.00	0.00	0.00
1.90	0.00	29.12	0.00	0.00	0.00	0.00	0.00
2.00	0.00	29.25	0.00	0.00	0.00	0.00	0.00

Table 210: Put option prices for November Nino 3.4 SST conditioned on IRI ensemble forecasts released in June

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.81	23.45	0.00	0.68	1.00	1.00	1.00
-1.90	0.78	23.61	0.00	0.61	0.95	1.00	1.00
-1.80	0.74	23.77	0.00	0.55	0.88	1.00	1.00
-1.70	0.70	23.93	0.00	0.48	0.80	1.00	1.00
-1.60	0.66	24.08	0.00	0.42	0.73	1.00	1.00
-1.50	0.61	24.24	0.00	0.35	0.66	0.96	1.00
-1.40	0.56	24.40	0.00	0.29	0.59	0.88	1.00
-1.30	0.51	24.56	0.00	0.22	0.51	0.80	1.00
-1.20	0.46	24.70	0.00	0.16	0.44	0.72	1.00
-1.10	0.40	24.86	0.00	0.10	0.37	0.65	1.00
-1.00	0.35	25.02	0.00	0.03	0.30	0.57	1.00
-0.90	0.29	25.18	0.00	0.00	0.22	0.48	1.00
-0.80	0.24	25.33	0.00	0.00	0.15	0.41	0.96
-0.70	0.19	25.49	0.00	0.00	0.08	0.33	0.87
-0.60	0.15	25.65	0.00	0.00	0.01	0.25	0.78
-0.50	0.12	25.81	0.00	0.00	0.00	0.17	0.70
-0.40	0.09	25.96	0.00	0.00	0.00	0.10	0.61
-0.30	0.06	26.12	0.00	0.00	0.00	0.02	0.52
-0.20	0.04	26.27	0.00	0.00	0.00	0.00	0.45
-0.10	0.03	26.43	0.00	0.00	0.00	0.00	0.37
0.00	0.02	26.58	0.00	0.00	0.00	0.00	0.30
0.10	0.01	26.75	0.00	0.00	0.00	0.00	0.21
0.20	0.01	26.89	0.00	0.00	0.00	0.00	0.15
0.30	0.01	27.06	0.00	0.00	0.00	0.00	0.08
0.40	0.00	27.22	0.00	0.00	0.00	0.00	0.00
0.50	0.00	27.37	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.52	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.68	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.83	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.99	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.15	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.30	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.46	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.62	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.77	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.93	0.00	0.00	0.00	0.00	0.00
1.60	0.00	29.09	0.00	0.00	0.00	0.00	0.00
1.70	0.00	29.25	0.00	0.00	0.00	0.00	0.00
1.80	0.00	29.40	0.00	0.00	0.00	0.00	0.00
1.90	0.00	29.55	0.00	0.00	0.00	0.00	0.00
2.00	0.00	29.72	0.00	0.00	0.00	0.00	0.00

Table 211: Put option prices for November Nino 3.4 SST conditioned on IRI ensemble forecasts released in May

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.80	23.12	0.00	0.67	1.00	1.00	1.00
-1.90	0.78	23.30	0.00	0.61	1.00	1.00	1.00
-1.80	0.75	23.46	0.00	0.55	1.00	1.00	1.00
-1.70	0.72	23.65	0.00	0.48	0.93	1.00	1.00
-1.60	0.69	23.82	0.00	0.41	0.86	1.00	1.00
-1.50	0.65	23.99	0.00	0.34	0.78	1.00	1.00
-1.40	0.61	24.16	0.00	0.29	0.69	1.00	1.00
-1.30	0.57	24.33	0.00	0.22	0.61	1.00	1.00
-1.20	0.52	24.50	0.00	0.15	0.54	0.92	1.00
-1.10	0.47	24.68	0.00	0.08	0.46	0.82	1.00
-1.00	0.42	24.85	0.00	0.02	0.38	0.73	1.00
-0.90	0.37	25.02	0.00	0.00	0.30	0.64	1.00
-0.80	0.31	25.20	0.00	0.00	0.21	0.55	1.00
-0.70	0.26	25.38	0.00	0.00	0.13	0.45	1.00
-0.60	0.21	25.54	0.00	0.00	0.05	0.37	1.00
-0.50	0.17	25.72	0.00	0.00	0.00	0.28	0.94
-0.40	0.13	25.89	0.00	0.00	0.00	0.19	0.84
-0.30	0.10	26.06	0.00	0.00	0.00	0.10	0.73
-0.20	0.07	26.24	0.00	0.00	0.00	0.01	0.64
-0.10	0.05	26.41	0.00	0.00	0.00	0.00	0.54
0.00	0.04	26.59	0.00	0.00	0.00	0.00	0.45
0.10	0.03	26.76	0.00	0.00	0.00	0.00	0.37
0.20	0.02	26.94	0.00	0.00	0.00	0.00	0.29
0.30	0.01	27.11	0.00	0.00	0.00	0.00	0.22
0.40	0.01	27.28	0.00	0.00	0.00	0.00	0.15
0.50	0.01	27.45	0.00	0.00	0.00	0.00	0.08
0.60	0.01	27.62	0.00	0.00	0.00	0.00	0.02
0.70	0.01	27.79	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.97	0.00	0.00	0.00	0.00	0.00
0.90	0.00	28.14	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.32	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.50	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.67	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.84	0.00	0.00	0.00	0.00	0.00
1.40	0.00	29.01	0.00	0.00	0.00	0.00	0.00
1.50	0.00	29.18	0.00	0.00	0.00	0.00	0.00
1.60	0.00	29.36	0.00	0.00	0.00	0.00	0.00
1.70	0.00	29.52	0.00	0.00	0.00	0.00	0.00
1.80	0.00	29.70	0.00	0.00	0.00	0.00	0.00
1.90	0.00	29.88	0.00	0.00	0.00	0.00	0.00
2.00	0.00	30.05	0.00	0.00	0.00	0.00	0.00

Table 212: Put option prices for November Nino 3.4 SST conditioned on IRI ensemble forecasts released in April

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.84	22.60	0.00	0.83	1.00	1.00	1.00
-1.90	0.82	22.80	0.00	0.77	1.00	1.00	1.00
-1.80	0.80	22.99	0.00	0.69	1.00	1.00	1.00
-1.70	0.78	23.20	0.00	0.62	1.00	1.00	1.00
-1.60	0.75	23.38	0.00	0.55	1.00	1.00	1.00
-1.50	0.72	23.58	0.00	0.48	0.97	1.00	1.00
-1.40	0.69	23.77	0.00	0.41	0.88	1.00	1.00
-1.30	0.65	23.98	0.00	0.34	0.79	1.00	1.00
-1.20	0.61	24.17	0.00	0.26	0.69	1.00	1.00
-1.10	0.56	24.36	0.00	0.19	0.61	1.00	1.00
-1.00	0.50	24.57	0.00	0.11	0.51	0.90	1.00
-0.90	0.45	24.76	0.00	0.04	0.42	0.80	1.00
-0.80	0.39	24.96	0.00	0.00	0.33	0.69	1.00
-0.70	0.33	25.16	0.00	0.00	0.23	0.59	1.00
-0.60	0.27	25.34	0.00	0.00	0.15	0.48	1.00
-0.50	0.22	25.55	0.00	0.00	0.05	0.38	1.00
-0.40	0.17	25.75	0.00	0.00	0.00	0.28	0.96
-0.30	0.13	25.94	0.00	0.00	0.00	0.18	0.84
-0.20	0.09	26.14	0.00	0.00	0.00	0.07	0.71
-0.10	0.06	26.34	0.00	0.00	0.00	0.00	0.61
0.00	0.05	26.53	0.00	0.00	0.00	0.00	0.50
0.10	0.03	26.73	0.00	0.00	0.00	0.00	0.40
0.20	0.02	26.92	0.00	0.00	0.00	0.00	0.32
0.30	0.02	27.12	0.00	0.00	0.00	0.00	0.23
0.40	0.01	27.32	0.00	0.00	0.00	0.00	0.15
0.50	0.01	27.52	0.00	0.00	0.00	0.00	0.10
0.60	0.01	27.71	0.00	0.00	0.00	0.00	0.02
0.70	0.01	27.90	0.00	0.00	0.00	0.00	0.00
0.80	0.00	28.11	0.00	0.00	0.00	0.00	0.00
0.90	0.00	28.31	0.00	0.00	0.00	0.00	0.00
1.00	0.00	28.49	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.70	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.89	0.00	0.00	0.00	0.00	0.00
1.30	0.00	29.08	0.00	0.00	0.00	0.00	0.00
1.40	0.00	29.28	0.00	0.00	0.00	0.00	0.00
1.50	0.00	29.49	0.00	0.00	0.00	0.00	0.00
1.60	0.00	29.68	0.00	0.00	0.00	0.00	0.00
1.70	0.00	29.87	0.00	0.00	0.00	0.00	0.00
1.80	0.00	30.07	0.00	0.00	0.00	0.00	0.00
1.90	0.00	30.26	0.00	0.00	0.00	0.00	0.00
2.00	0.00	30.46	0.00	0.00	0.00	0.00	0.00

Table 213: Put option prices for November Nino 3.4 SST conditioned on IRI ensemble forecasts released in March

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.75	22.95	0.00	0.54	1.00	1.00	1.00
-1.90	0.74	23.12	0.00	0.49	1.00	1.00	1.00
-1.80	0.72	23.32	0.00	0.42	1.00	1.00	1.00
-1.70	0.69	23.51	0.00	0.37	1.00	1.00	1.00
-1.60	0.67	23.69	0.00	0.30	0.92	1.00	1.00
-1.50	0.64	23.88	0.00	0.24	0.83	1.00	1.00
-1.40	0.61	24.06	0.00	0.18	0.74	1.00	1.00
-1.30	0.57	24.26	0.00	0.12	0.65	1.00	1.00
-1.20	0.53	24.44	0.00	0.06	0.56	1.00	1.00
-1.10	0.49	24.64	0.00	0.00	0.47	0.96	1.00
-1.00	0.44	24.82	0.00	0.00	0.39	0.84	1.00
-0.90	0.39	25.00	0.00	0.00	0.31	0.74	1.00
-0.80	0.34	25.20	0.00	0.00	0.22	0.63	1.00
-0.70	0.29	25.39	0.00	0.00	0.13	0.52	1.00
-0.60	0.24	25.58	0.00	0.00	0.04	0.42	1.00
-0.50	0.19	25.76	0.00	0.00	0.00	0.32	1.00
-0.40	0.15	25.96	0.00	0.00	0.00	0.22	0.98
-0.30	0.11	26.14	0.00	0.00	0.00	0.12	0.86
-0.20	0.08	26.32	0.00	0.00	0.00	0.02	0.73
-0.10	0.06	26.51	0.00	0.00	0.00	0.00	0.62
0.00	0.04	26.70	0.00	0.00	0.00	0.00	0.53
0.10	0.03	26.89	0.00	0.00	0.00	0.00	0.44
0.20	0.03	27.08	0.00	0.00	0.00	0.00	0.37
0.30	0.02	27.26	0.00	0.00	0.00	0.00	0.30
0.40	0.02	27.45	0.00	0.00	0.00	0.00	0.26
0.50	0.01	27.64	0.00	0.00	0.00	0.00	0.19
0.60	0.01	27.82	0.00	0.00	0.00	0.00	0.15
0.70	0.01	28.01	0.00	0.00	0.00	0.00	0.13
0.80	0.01	28.21	0.00	0.00	0.00	0.00	0.09
0.90	0.01	28.38	0.00	0.00	0.00	0.00	0.07
1.00	0.01	28.58	0.00	0.00	0.00	0.00	0.04
1.10	0.01	28.76	0.00	0.00	0.00	0.00	0.02
1.20	0.01	28.96	0.00	0.00	0.00	0.00	0.01
1.30	0.01	29.14	0.00	0.00	0.00	0.00	0.01
1.40	0.01	29.32	0.00	0.00	0.00	0.00	0.00
1.50	0.01	29.53	0.00	0.00	0.00	0.00	0.00
1.60	0.01	29.71	0.00	0.00	0.00	0.00	0.00
1.70	0.01	29.89	0.00	0.00	0.00	0.00	0.00
1.80	0.01	30.09	0.00	0.00	0.00	0.00	0.00
1.90	0.01	30.27	0.00	0.00	0.00	0.00	0.00
2.00	0.01	30.45	0.00	0.00	0.00	0.00	0.00

Table 214: Put option prices for November Nino 3.4 SST conditioned on IRI ensemble forecasts released in February

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.41	25.29	0.00	0.00	0.19	1.00	1.00
-1.90	0.40	25.34	0.00	0.00	0.15	1.00	1.00
-1.80	0.39	25.40	0.00	0.00	0.13	0.99	1.00
-1.70	0.37	25.47	0.00	0.00	0.10	0.92	1.00
-1.60	0.36	25.53	0.00	0.00	0.07	0.84	1.00
-1.50	0.34	25.60	0.00	0.00	0.03	0.78	1.00
-1.40	0.33	25.66	0.00	0.00	0.01	0.72	1.00
-1.30	0.31	25.73	0.00	0.00	0.00	0.65	1.00
-1.20	0.29	25.79	0.00	0.00	0.00	0.59	1.00
-1.10	0.27	25.86	0.00	0.00	0.00	0.52	1.00
-1.00	0.25	25.92	0.00	0.00	0.00	0.46	1.00
-0.90	0.23	25.98	0.00	0.00	0.00	0.40	1.00
-0.80	0.20	26.04	0.00	0.00	0.00	0.33	1.00
-0.70	0.18	26.11	0.00	0.00	0.00	0.28	1.00
-0.60	0.16	26.17	0.00	0.00	0.00	0.22	1.00
-0.50	0.14	26.23	0.00	0.00	0.00	0.17	1.00
-0.40	0.12	26.30	0.00	0.00	0.00	0.11	1.00
-0.30	0.11	26.36	0.00	0.00	0.00	0.07	0.95
-0.20	0.10	26.42	0.00	0.00	0.00	0.02	0.88
-0.10	0.08	26.51	0.00	0.00	0.00	0.00	0.80
0.00	0.08	26.55	0.00	0.00	0.00	0.00	0.77
0.10	0.07	26.62	0.00	0.00	0.00	0.00	0.73
0.20	0.07	26.68	0.00	0.00	0.00	0.00	0.71
0.30	0.06	26.75	0.00	0.00	0.00	0.00	0.72
0.40	0.06	26.81	0.00	0.00	0.00	0.00	0.74
0.50	0.07	26.86	0.00	0.00	0.00	0.00	0.77
0.60	0.07	26.92	0.00	0.00	0.00	0.00	0.81
0.70	0.07	27.00	0.00	0.00	0.00	0.00	0.87
0.80	0.08	27.06	0.00	0.00	0.00	0.00	0.92
0.90	0.08	27.12	0.00	0.00	0.00	0.00	0.98
1.00	0.09	27.18	0.00	0.00	0.00	0.00	1.00
1.10	0.09	27.24	0.00	0.00	0.00	0.00	1.00
1.20	0.10	27.31	0.00	0.00	0.00	0.00	1.00
1.30	0.10	27.38	0.00	0.00	0.00	0.00	1.00
1.40	0.11	27.43	0.00	0.00	0.00	0.00	1.00
1.50	0.11	27.51	0.00	0.00	0.00	0.00	1.00
1.60	0.12	27.57	0.00	0.00	0.00	0.00	1.00
1.70	0.12	27.63	0.00	0.00	0.00	0.00	1.00
1.80	0.13	27.70	0.00	0.00	0.00	0.00	1.00
1.90	0.13	27.76	0.00	0.00	0.00	0.00	1.00
2.00	0.14	27.82	0.00	0.00	0.00	0.00	1.00

Table 215: Put option prices for November Nino 3.4 SST conditioned on IRI ensemble forecasts released in January

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.40	25.75	0.00	0.00	0.00	1.00	1.00
-1.90	0.39	25.78	0.00	0.00	0.00	1.00	1.00
-1.80	0.38	25.84	0.00	0.00	0.00	1.00	1.00
-1.70	0.37	25.88	0.00	0.00	0.00	1.00	1.00
-1.60	0.36	25.92	0.00	0.00	0.00	1.00	1.00
-1.50	0.35	25.97	0.00	0.00	0.00	0.94	1.00
-1.40	0.33	26.02	0.00	0.00	0.00	0.85	1.00
-1.30	0.32	26.06	0.00	0.00	0.00	0.78	1.00
-1.20	0.30	26.10	0.00	0.00	0.00	0.70	1.00
-1.10	0.29	26.14	0.00	0.00	0.00	0.63	1.00
-1.00	0.27	26.20	0.00	0.00	0.00	0.54	1.00
-0.90	0.25	26.24	0.00	0.00	0.00	0.47	1.00
-0.80	0.23	26.29	0.00	0.00	0.00	0.38	1.00
-0.70	0.20	26.32	0.00	0.00	0.00	0.31	1.00
-0.60	0.18	26.38	0.00	0.00	0.00	0.23	1.00
-0.50	0.16	26.43	0.00	0.00	0.00	0.17	1.00
-0.40	0.14	26.47	0.00	0.00	0.00	0.11	1.00
-0.30	0.12	26.51	0.00	0.00	0.00	0.05	1.00
-0.20	0.10	26.55	0.00	0.00	0.00	0.01	0.97
-0.10	0.09	26.60	0.00	0.00	0.00	0.00	0.89
0.00	0.08	26.64	0.00	0.00	0.00	0.00	0.82
0.10	0.08	26.69	0.00	0.00	0.00	0.00	0.80
0.20	0.08	26.72	0.00	0.00	0.00	0.00	0.84
0.30	0.08	26.78	0.00	0.00	0.00	0.00	0.88
0.40	0.09	26.82	0.00	0.00	0.00	0.00	0.97
0.50	0.10	26.87	0.00	0.00	0.00	0.00	1.00
0.60	0.11	26.91	0.00	0.00	0.00	0.00	1.00
0.70	0.12	26.96	0.00	0.00	0.00	0.00	1.00
0.80	0.13	27.00	0.00	0.00	0.00	0.01	1.00
0.90	0.14	27.05	0.00	0.00	0.00	0.04	1.00
1.00	0.16	27.08	0.00	0.00	0.00	0.09	1.00
1.10	0.17	27.13	0.00	0.00	0.00	0.12	1.00
1.20	0.18	27.18	0.00	0.00	0.00	0.15	1.00
1.30	0.19	27.22	0.00	0.00	0.00	0.19	1.00
1.40	0.20	27.26	0.00	0.00	0.00	0.23	1.00
1.50	0.21	27.31	0.00	0.00	0.00	0.27	1.00
1.60	0.22	27.35	0.00	0.00	0.00	0.32	1.00
1.70	0.23	27.40	0.00	0.00	0.00	0.35	1.00
1.80	0.24	27.44	0.00	0.00	0.00	0.40	1.00
1.90	0.24	27.49	0.00	0.00	0.00	0.44	1.00
2.00	0.25	27.53	0.00	0.00	0.00	0.48	1.00

Appendix O: December Pricing

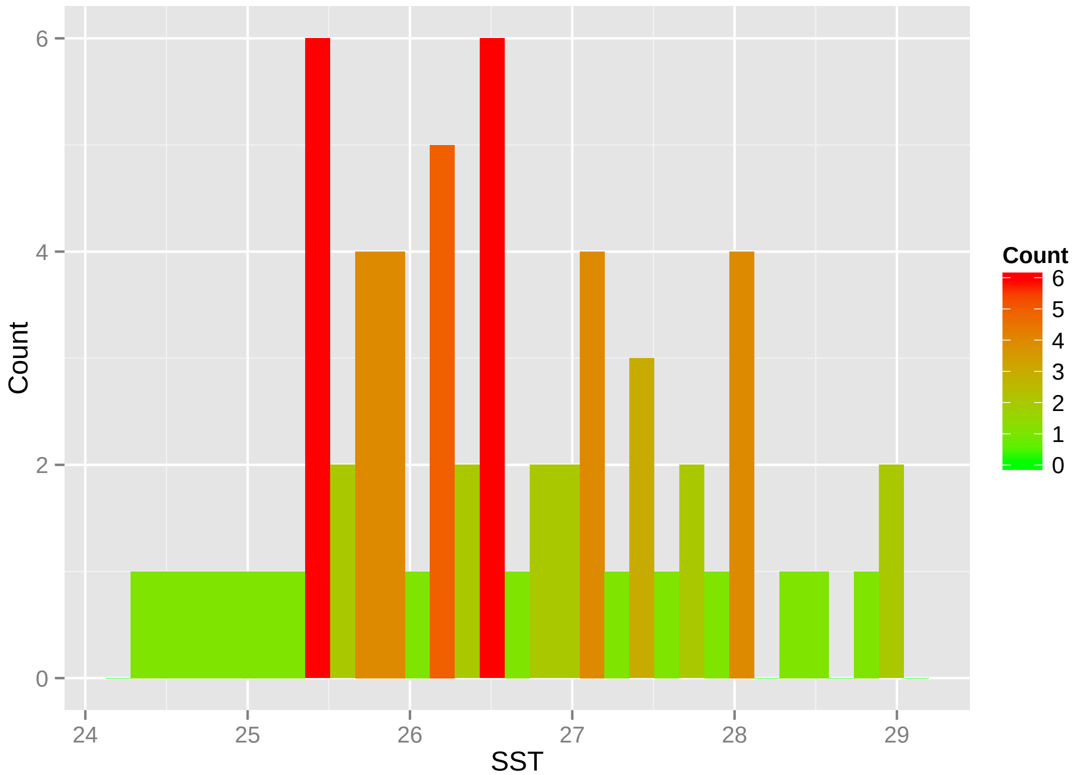


Figure 111: Histogram of December SST for Niño 3.4 ERSST.3b

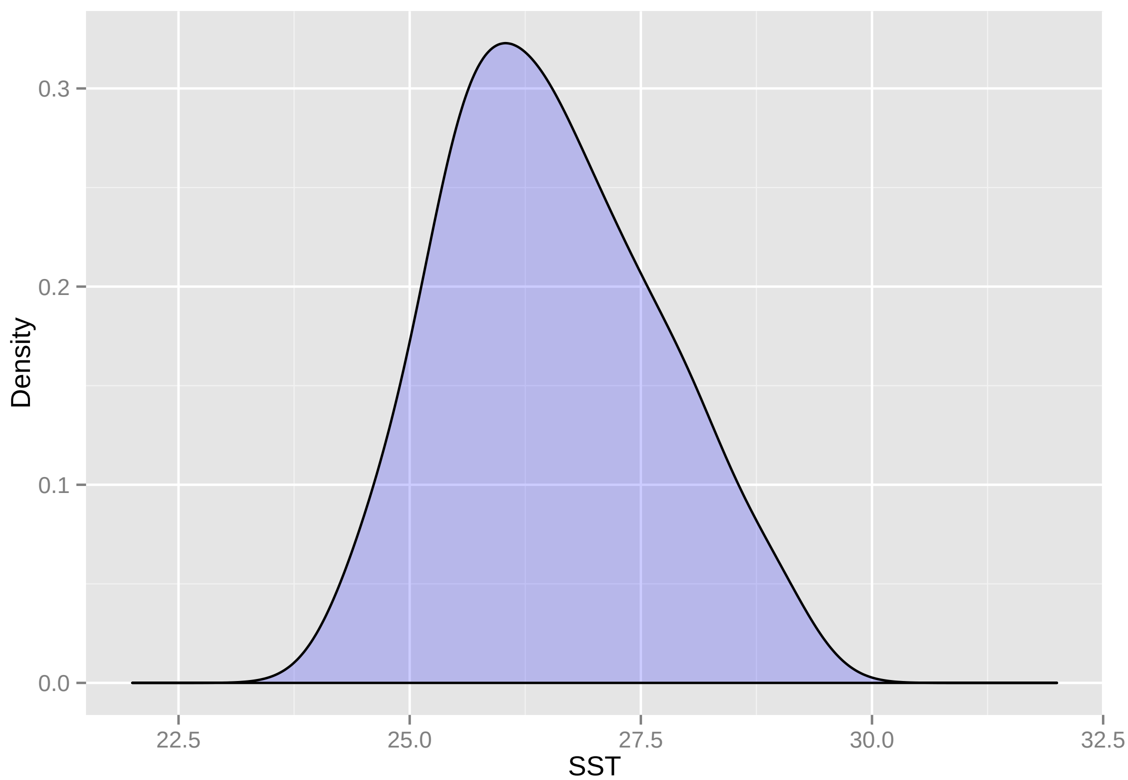


Figure 112: Kernel density estimate of December SST for Niño 3.4 ERSST.3b

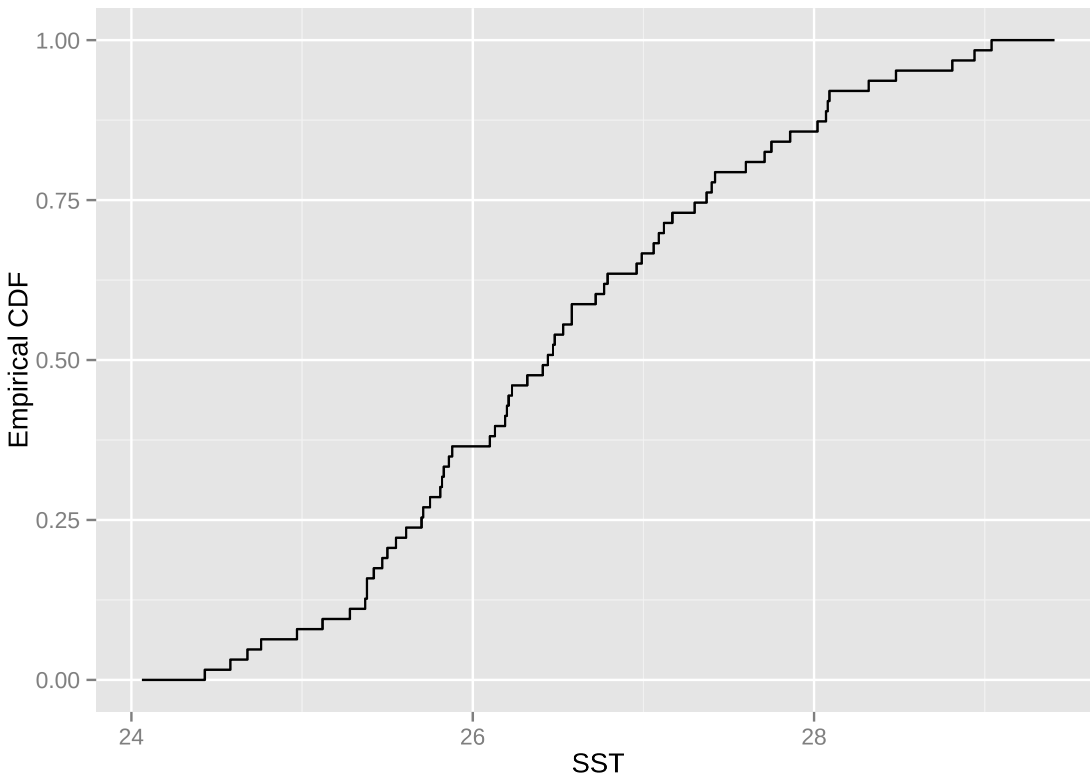


Figure 113: ECDF of December SST for Niño 3.4 ERSST.3b

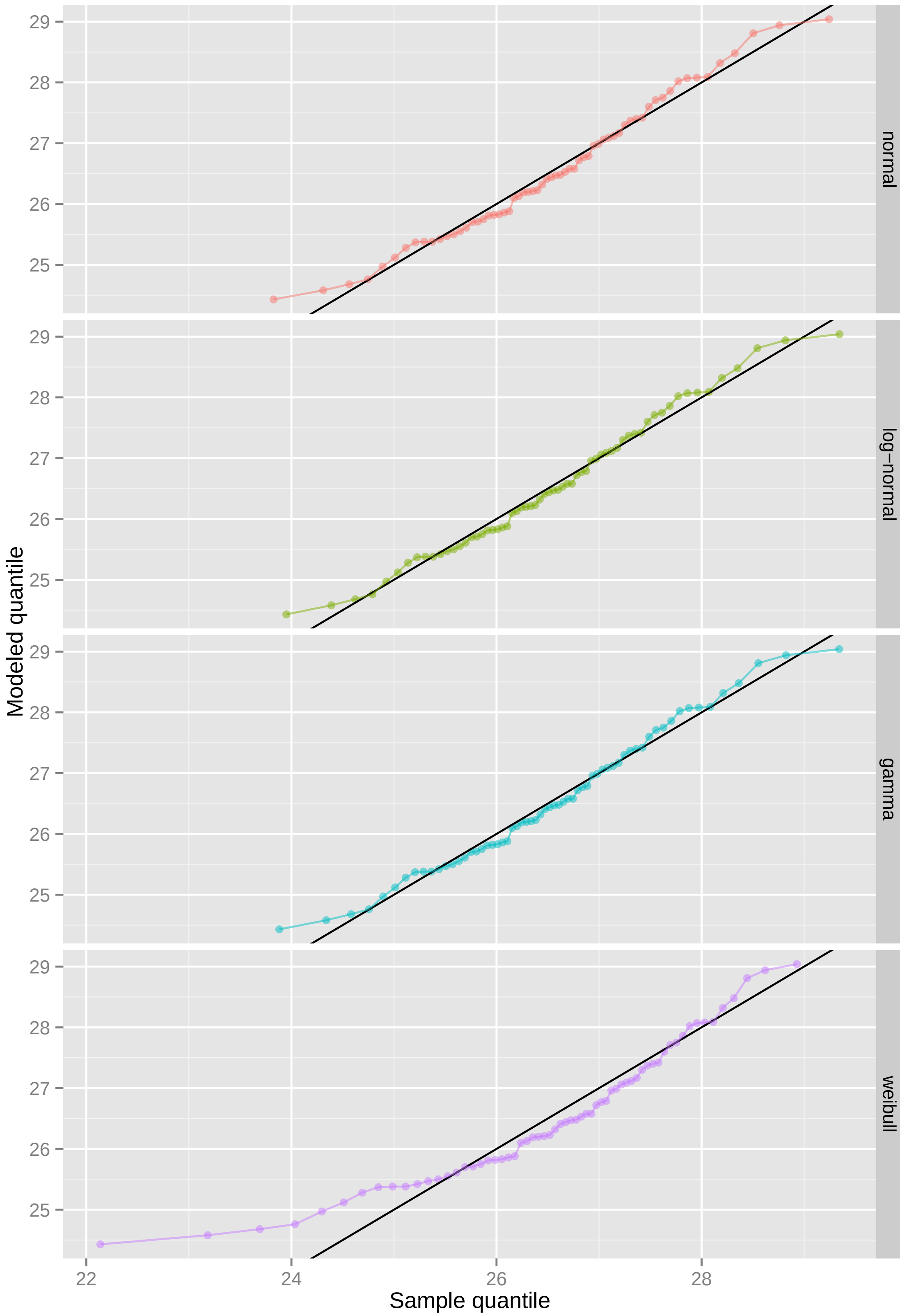


Figure 114: QQ plots of December SST for Niño 3.4 ERSST.3b compared to samples from various distributions (n=2 million)

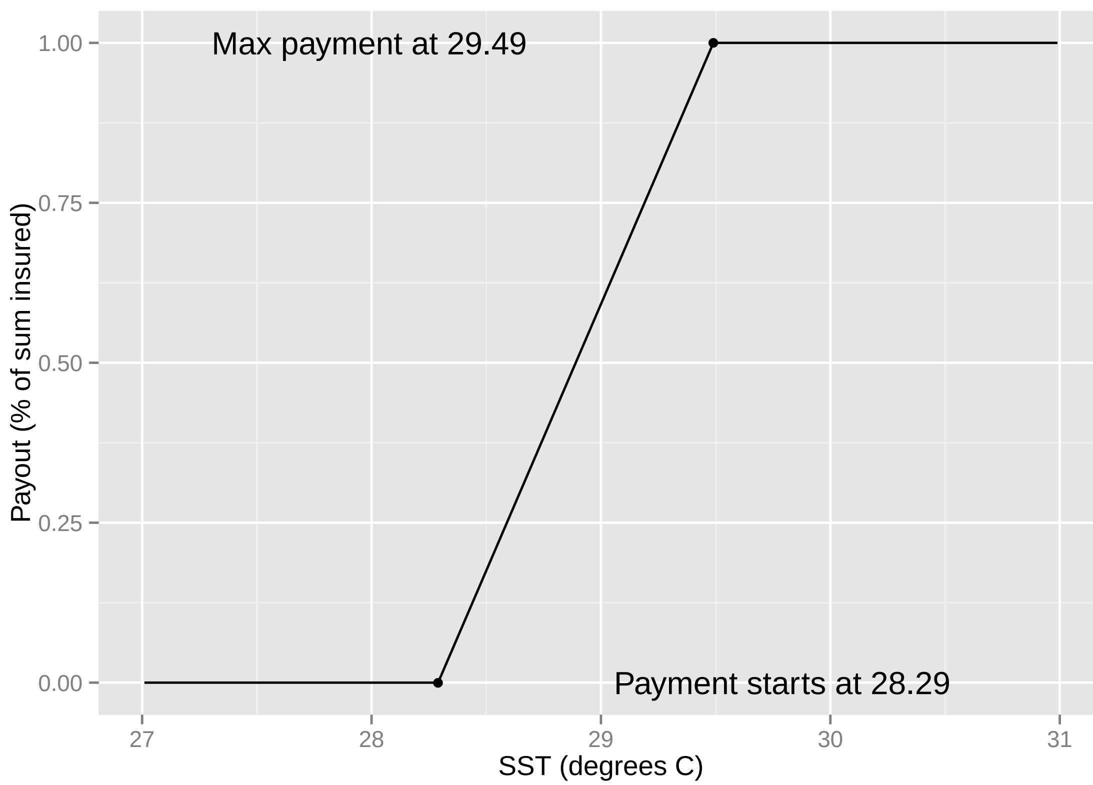


Figure 115: Payout function for call option on December SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations above the baseline

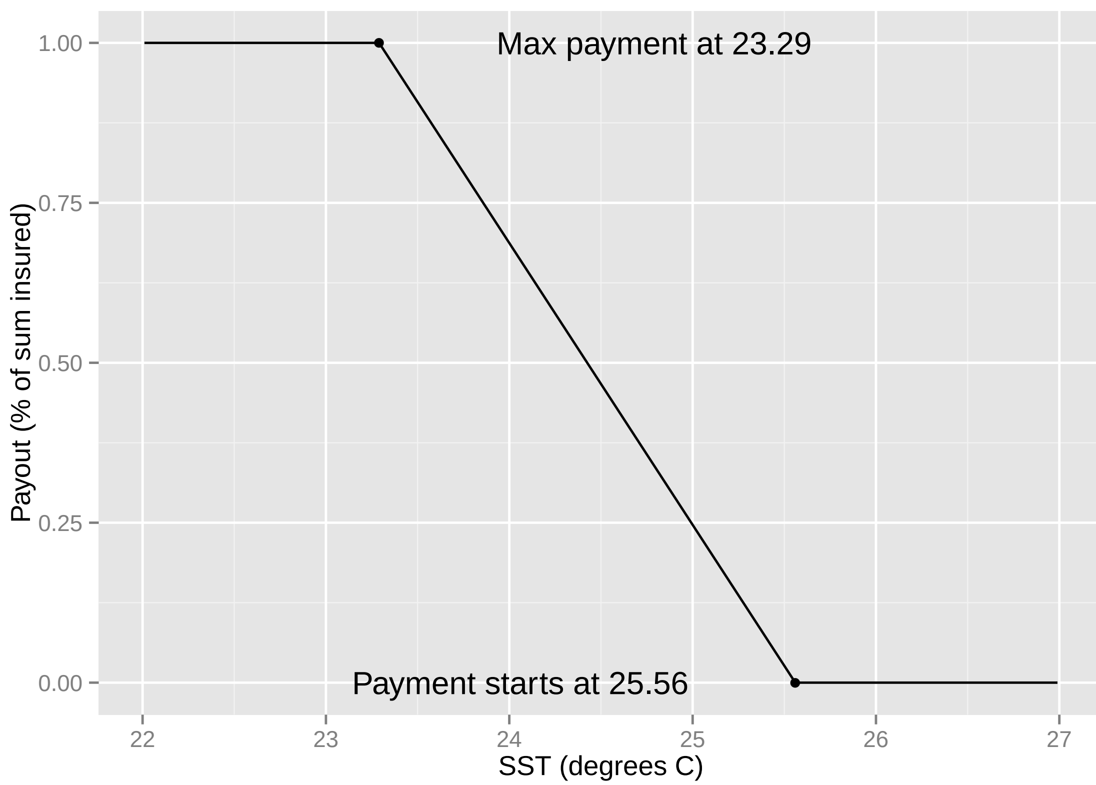


Figure 116: Payout function for put option on December SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

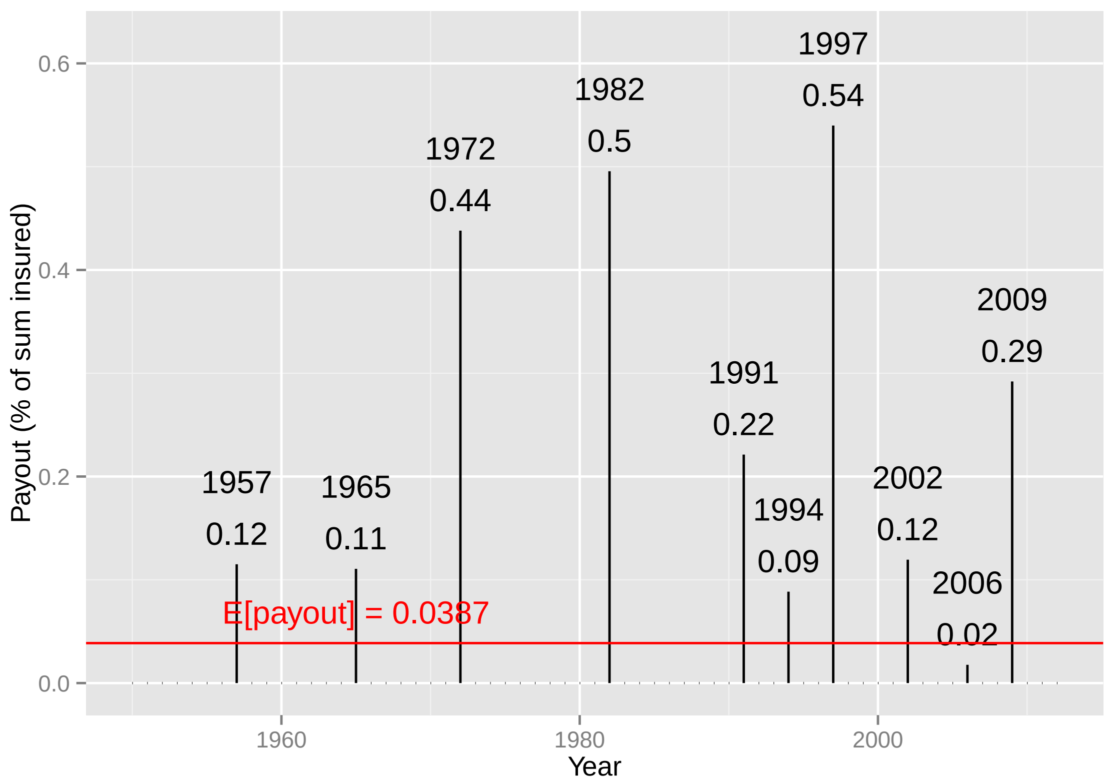


Figure 117: Historical burn on call option for December SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations above the baseline

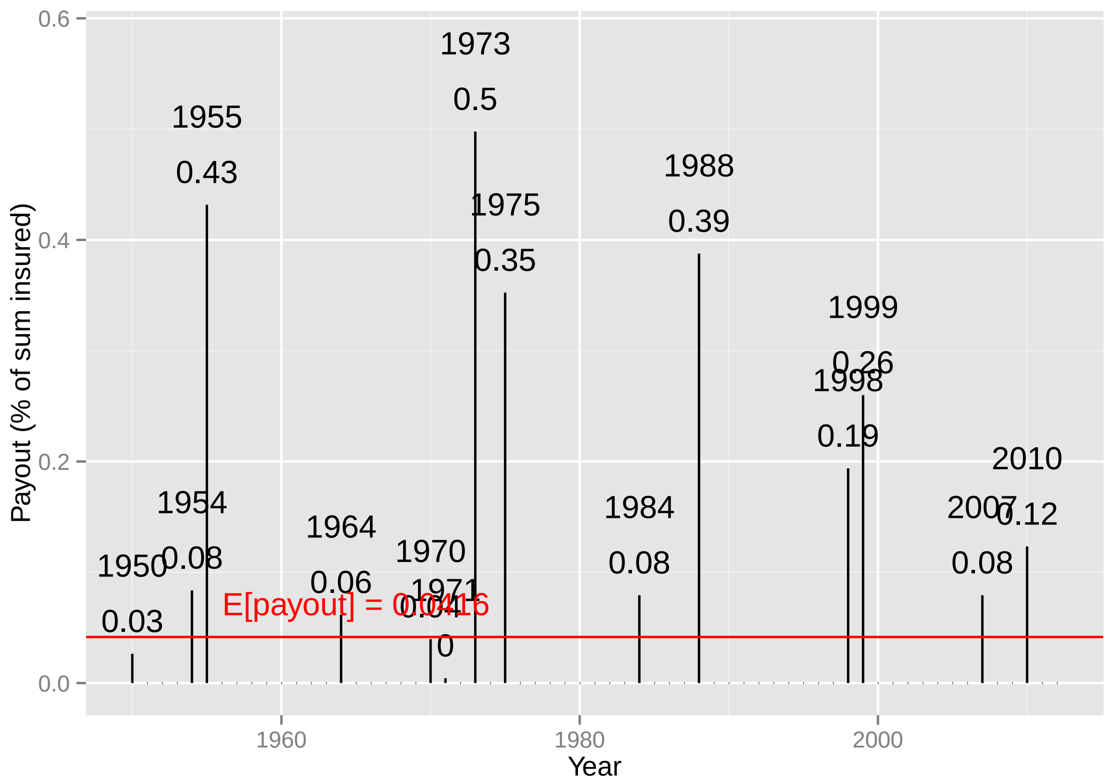


Figure 118: Historical burn on put option on December SST for Niño 3.4 ERSST.3b covering index values between one and three standard deviations below the baseline

Table 216: Bayesian regression linking December Niño 3.4 SST anomalies to average of relevant IRI ensemble forecasts

	mean	sd	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q	n_eff	Rhat
October forecast average covering December Niño 3.4 SST anomalies									
α	-0.20	0.20	-0.60	-0.30	-0.20	-0.10	0.20	93906	1
β	1.10	0.20	0.60	0.90	1.10	1.20	1.50	95785	1
σ_y^2	0.50	0.30	0.20	0.30	0.40	0.60	1.20	56749	1
September forecast average covering December Niño 3.4 SST anomalies									
α	-0.30	0.20	-0.80	-0.40	-0.30	-0.10	0.20	92894	1
β	1.10	0.30	0.60	1.00	1.10	1.30	1.70	92393	1
σ_y^2	0.60	0.40	0.20	0.40	0.50	0.70	1.60	56620	1
August forecast average covering December Niño 3.4 SST anomalies									
α	-0.40	0.30	-0.90	-0.50	-0.40	-0.20	0.20	86910	1
β	1.20	0.40	0.50	1.00	1.20	1.50	1.90	91651	1
σ_y^2	0.70	0.40	0.30	0.50	0.60	0.90	1.90	57308	1
July forecast average covering December Niño 3.4 SST anomalies									
α	-0.40	0.30	-1.00	-0.50	-0.40	-0.20	0.30	92055	1
β	1.30	0.50	0.40	1.10	1.30	1.60	2.30	88143	1
σ_y^2	0.90	0.60	0.30	0.50	0.80	1.10	2.50	53760	1
June forecast average covering December Niño 3.4 SST anomalies									
α	-0.30	0.30	-0.90	-0.50	-0.30	-0.10	0.30	97580	1
β	1.50	0.60	0.40	1.20	1.50	1.90	2.60	93445	1
σ_y^2	0.90	0.60	0.30	0.60	0.80	1.10	2.40	58643	1
May forecast average covering December Niño 3.4 SST anomalies									
α	-0.30	0.30	-0.90	-0.50	-0.30	-0.10	0.40	93385	1
β	1.70	0.80	0.10	1.20	1.70	2.20	3.40	93731	1
σ_y^2	1.20	0.70	0.40	0.70	1.00	1.40	3.00	60858	1
April forecast average covering December Niño 3.4 SST anomalies									
α	-0.30	0.40	-1.00	-0.60	-0.30	-0.10	0.40	88023	1
β	1.90	1.00	-0.10	1.20	1.90	2.50	3.80	84802	1
σ_y^2	1.30	0.80	0.50	0.80	1.10	1.50	3.30	54778	1
March forecast average covering December Niño 3.4 SST anomalies									
α	-0.20	0.40	-0.90	-0.40	-0.20	0.10	0.60	100664	1
β	1.70	1.20	-0.80	0.90	1.70	2.50	4.10	96425	1
σ_y^2	1.50	0.90	0.60	0.90	1.30	1.80	3.80	60833	1
February forecast average covering December Niño 3.4 SST anomalies									
α	-0.40	0.50	-1.30	-0.70	-0.40	-0.10	0.50	92356	1
β	0.50	1.70	-3.00	-0.50	0.50	1.60	3.90	81189	1
σ_y^2	2.00	1.80	0.60	1.10	1.50	2.40	6.30	53449	1

Table 217: Call option prices for December Nino 3.4 SST conditioned on IRI ensemble forecasts released in October

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	24.38	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	24.49	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.60	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.70	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.81	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.91	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	25.02	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	25.13	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	25.23	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.34	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.45	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.55	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.66	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.77	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.87	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	25.97	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	26.09	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.19	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.29	0.00	0.00	0.00	0.00	0.00
-0.10	0.00	26.40	0.00	0.00	0.00	0.00	0.01
0.00	0.01	26.50	0.00	0.00	0.00	0.00	0.06
0.10	0.01	26.61	0.00	0.00	0.00	0.00	0.10
0.20	0.01	26.72	0.00	0.00	0.00	0.00	0.14
0.30	0.01	26.83	0.00	0.00	0.00	0.00	0.20
0.40	0.02	26.93	0.00	0.00	0.00	0.00	0.25
0.50	0.02	27.03	0.00	0.00	0.00	0.00	0.30
0.60	0.03	27.14	0.00	0.00	0.00	0.00	0.34
0.70	0.04	27.26	0.00	0.00	0.00	0.00	0.40
0.80	0.05	27.35	0.00	0.00	0.00	0.00	0.44
0.90	0.06	27.46	0.00	0.00	0.00	0.04	0.50
1.00	0.08	27.57	0.00	0.00	0.00	0.10	0.55
1.10	0.10	27.68	0.00	0.00	0.00	0.14	0.60
1.20	0.12	27.79	0.00	0.00	0.00	0.19	0.66
1.30	0.15	27.89	0.00	0.00	0.03	0.24	0.70
1.40	0.17	27.99	0.00	0.00	0.08	0.29	0.77
1.50	0.20	28.10	0.00	0.00	0.12	0.34	0.82
1.60	0.24	28.20	0.00	0.00	0.17	0.39	0.86
1.70	0.27	28.31	0.00	0.00	0.22	0.44	0.93
1.80	0.31	28.42	0.00	0.04	0.26	0.49	0.99
1.90	0.35	28.53	0.00	0.09	0.32	0.54	1.00
2.00	0.38	28.63	0.00	0.13	0.36	0.59	1.00

Table 218: Call option prices for December Nino 3.4 SST conditioned on IRI ensemble forecasts released in September

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	24.11	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	24.22	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.34	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.44	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.57	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.68	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	24.80	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	24.91	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	25.02	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	25.15	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.25	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.37	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.48	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.60	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.71	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	25.83	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	25.94	0.00	0.00	0.00	0.00	0.00
-0.30	0.00	26.06	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	26.17	0.00	0.00	0.00	0.00	0.00
-0.10	0.01	26.29	0.00	0.00	0.00	0.00	0.05
0.00	0.01	26.41	0.00	0.00	0.00	0.00	0.10
0.10	0.01	26.51	0.00	0.00	0.00	0.00	0.14
0.20	0.01	26.63	0.00	0.00	0.00	0.00	0.19
0.30	0.02	26.75	0.00	0.00	0.00	0.00	0.24
0.40	0.02	26.86	0.00	0.00	0.00	0.00	0.30
0.50	0.03	26.98	0.00	0.00	0.00	0.00	0.36
0.60	0.04	27.09	0.00	0.00	0.00	0.00	0.40
0.70	0.05	27.21	0.00	0.00	0.00	0.00	0.46
0.80	0.06	27.32	0.00	0.00	0.00	0.01	0.51
0.90	0.07	27.43	0.00	0.00	0.00	0.06	0.58
1.00	0.09	27.55	0.00	0.00	0.00	0.11	0.64
1.10	0.11	27.67	0.00	0.00	0.00	0.17	0.69
1.20	0.14	27.79	0.00	0.00	0.00	0.22	0.76
1.30	0.17	27.90	0.00	0.00	0.03	0.28	0.81
1.40	0.20	28.01	0.00	0.00	0.08	0.33	0.87
1.50	0.23	28.13	0.00	0.00	0.14	0.38	0.94
1.60	0.26	28.24	0.00	0.00	0.19	0.43	0.99
1.70	0.30	28.36	0.00	0.00	0.24	0.49	1.00
1.80	0.34	28.47	0.00	0.03	0.29	0.54	1.00
1.90	0.37	28.58	0.00	0.08	0.34	0.60	1.00
2.00	0.41	28.70	0.00	0.12	0.39	0.66	1.00

Table 219: Call option prices for December Nino 3.4 SST conditioned on IRI ensemble forecasts released in August

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	23.89	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	24.01	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	24.13	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.27	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.37	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.50	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	24.63	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	24.74	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	24.87	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	24.99	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	25.12	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.23	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.36	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.48	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	25.61	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	25.73	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	25.85	0.00	0.00	0.00	0.00	0.00
-0.30	0.01	25.98	0.00	0.00	0.00	0.00	0.00
-0.20	0.01	26.10	0.00	0.00	0.00	0.00	0.04
-0.10	0.01	26.22	0.00	0.00	0.00	0.00	0.09
0.00	0.01	26.35	0.00	0.00	0.00	0.00	0.13
0.10	0.01	26.46	0.00	0.00	0.00	0.00	0.18
0.20	0.02	26.59	0.00	0.00	0.00	0.00	0.25
0.30	0.02	26.71	0.00	0.00	0.00	0.00	0.29
0.40	0.03	26.83	0.00	0.00	0.00	0.00	0.35
0.50	0.03	26.95	0.00	0.00	0.00	0.00	0.40
0.60	0.04	27.07	0.00	0.00	0.00	0.00	0.47
0.70	0.05	27.20	0.00	0.00	0.00	0.00	0.52
0.80	0.07	27.32	0.00	0.00	0.00	0.03	0.59
0.90	0.09	27.44	0.00	0.00	0.00	0.08	0.64
1.00	0.11	27.57	0.00	0.00	0.00	0.14	0.70
1.10	0.13	27.69	0.00	0.00	0.00	0.20	0.77
1.20	0.16	27.82	0.00	0.00	0.00	0.26	0.84
1.30	0.19	27.94	0.00	0.00	0.05	0.32	0.91
1.40	0.22	28.05	0.00	0.00	0.10	0.37	0.97
1.50	0.26	28.18	0.00	0.00	0.16	0.43	1.00
1.60	0.29	28.30	0.00	0.00	0.21	0.49	1.00
1.70	0.33	28.43	0.00	0.00	0.27	0.55	1.00
1.80	0.37	28.54	0.00	0.03	0.32	0.61	1.00
1.90	0.41	28.66	0.00	0.08	0.37	0.67	1.00
2.00	0.45	28.79	0.00	0.13	0.43	0.73	1.00

Table 220: Call option prices for December Nino 3.4 SST conditioned on IRI ensemble forecasts released in July

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	23.64	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	23.78	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	23.91	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	24.05	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	24.18	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.31	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	24.45	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	24.58	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	24.71	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	24.85	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	24.99	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.12	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.26	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.39	0.00	0.00	0.00	0.00	0.00
-0.60	0.01	25.52	0.00	0.00	0.00	0.00	0.00
-0.50	0.01	25.66	0.00	0.00	0.00	0.00	0.00
-0.40	0.01	25.79	0.00	0.00	0.00	0.00	0.02
-0.30	0.01	25.93	0.00	0.00	0.00	0.00	0.09
-0.20	0.01	26.06	0.00	0.00	0.00	0.00	0.12
-0.10	0.01	26.20	0.00	0.00	0.00	0.00	0.19
0.00	0.02	26.32	0.00	0.00	0.00	0.00	0.23
0.10	0.02	26.47	0.00	0.00	0.00	0.00	0.30
0.20	0.02	26.60	0.00	0.00	0.00	0.00	0.35
0.30	0.03	26.73	0.00	0.00	0.00	0.00	0.42
0.40	0.04	26.87	0.00	0.00	0.00	0.00	0.47
0.50	0.05	27.01	0.00	0.00	0.00	0.00	0.54
0.60	0.06	27.14	0.00	0.00	0.00	0.00	0.61
0.70	0.08	27.27	0.00	0.00	0.00	0.04	0.68
0.80	0.10	27.41	0.00	0.00	0.00	0.10	0.76
0.90	0.12	27.54	0.00	0.00	0.00	0.17	0.83
1.00	0.15	27.68	0.00	0.00	0.00	0.23	0.90
1.10	0.18	27.82	0.00	0.00	0.00	0.30	0.98
1.20	0.21	27.95	0.00	0.00	0.06	0.36	1.00
1.30	0.25	28.08	0.00	0.00	0.12	0.43	1.00
1.40	0.28	28.22	0.00	0.00	0.17	0.49	1.00
1.50	0.32	28.35	0.00	0.00	0.24	0.56	1.00
1.60	0.36	28.49	0.00	0.00	0.30	0.62	1.00
1.70	0.40	28.63	0.00	0.02	0.35	0.70	1.00
1.80	0.44	28.75	0.00	0.06	0.41	0.75	1.00
1.90	0.48	28.88	0.00	0.12	0.47	0.82	1.00
2.00	0.52	29.03	0.00	0.18	0.54	0.89	1.00

Table 221: Call option prices for December Nino 3.4 SST conditioned on IRI ensemble forecasts released in June

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.00	23.37	0.00	0.00	0.00	0.00	0.00
-1.90	0.00	23.52	0.00	0.00	0.00	0.00	0.00
-1.80	0.00	23.68	0.00	0.00	0.00	0.00	0.00
-1.70	0.00	23.83	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	23.97	0.00	0.00	0.00	0.00	0.00
-1.50	0.00	24.13	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	24.28	0.00	0.00	0.00	0.00	0.00
-1.30	0.00	24.44	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	24.59	0.00	0.00	0.00	0.00	0.00
-1.10	0.00	24.74	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	24.89	0.00	0.00	0.00	0.00	0.00
-0.90	0.00	25.04	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	25.20	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	25.34	0.00	0.00	0.00	0.00	0.00
-0.60	0.01	25.49	0.00	0.00	0.00	0.00	0.00
-0.50	0.01	25.65	0.00	0.00	0.00	0.00	0.00
-0.40	0.01	25.79	0.00	0.00	0.00	0.00	0.03
-0.30	0.01	25.96	0.00	0.00	0.00	0.00	0.09
-0.20	0.01	26.10	0.00	0.00	0.00	0.00	0.14
-0.10	0.01	26.26	0.00	0.00	0.00	0.00	0.21
0.00	0.02	26.41	0.00	0.00	0.00	0.00	0.26
0.10	0.02	26.55	0.00	0.00	0.00	0.00	0.32
0.20	0.03	26.71	0.00	0.00	0.00	0.00	0.40
0.30	0.04	26.86	0.00	0.00	0.00	0.00	0.46
0.40	0.05	27.01	0.00	0.00	0.00	0.00	0.54
0.50	0.07	27.17	0.00	0.00	0.00	0.00	0.62
0.60	0.09	27.32	0.00	0.00	0.00	0.06	0.69
0.70	0.11	27.48	0.00	0.00	0.00	0.14	0.77
0.80	0.14	27.63	0.00	0.00	0.00	0.21	0.86
0.90	0.17	27.78	0.00	0.00	0.00	0.28	0.95
1.00	0.21	27.93	0.00	0.00	0.05	0.35	1.00
1.10	0.25	28.08	0.00	0.00	0.12	0.43	1.00
1.20	0.29	28.23	0.00	0.00	0.18	0.50	1.00
1.30	0.33	28.37	0.00	0.00	0.24	0.57	1.00
1.40	0.38	28.54	0.00	0.00	0.32	0.65	1.00
1.50	0.42	28.68	0.00	0.04	0.38	0.73	1.00
1.60	0.47	28.83	0.00	0.09	0.45	0.80	1.00
1.70	0.51	28.99	0.00	0.15	0.51	0.88	1.00
1.80	0.55	29.14	0.00	0.21	0.58	0.96	1.00
1.90	0.59	29.30	0.00	0.27	0.65	1.00	1.00
2.00	0.63	29.45	0.00	0.33	0.72	1.00	1.00

Table 222: Call option prices for December Nino 3.4 SST conditioned on IRI ensemble forecasts released in May

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.01	23.01	0.00	0.00	0.00	0.00	0.00
-1.90	0.01	23.18	0.00	0.00	0.00	0.00	0.00
-1.80	0.01	23.35	0.00	0.00	0.00	0.00	0.00
-1.70	0.01	23.52	0.00	0.00	0.00	0.00	0.00
-1.60	0.01	23.70	0.00	0.00	0.00	0.00	0.00
-1.50	0.01	23.87	0.00	0.00	0.00	0.00	0.00
-1.40	0.01	24.03	0.00	0.00	0.00	0.00	0.00
-1.30	0.01	24.20	0.00	0.00	0.00	0.00	0.00
-1.20	0.01	24.38	0.00	0.00	0.00	0.00	0.00
-1.10	0.01	24.56	0.00	0.00	0.00	0.00	0.00
-1.00	0.01	24.73	0.00	0.00	0.00	0.00	0.00
-0.90	0.01	24.89	0.00	0.00	0.00	0.00	0.00
-0.80	0.01	25.07	0.00	0.00	0.00	0.00	0.00
-0.70	0.01	25.23	0.00	0.00	0.00	0.00	0.03
-0.60	0.01	25.40	0.00	0.00	0.00	0.00	0.06
-0.50	0.01	25.57	0.00	0.00	0.00	0.00	0.12
-0.40	0.01	25.75	0.00	0.00	0.00	0.00	0.17
-0.30	0.01	25.91	0.00	0.00	0.00	0.00	0.21
-0.20	0.02	26.09	0.00	0.00	0.00	0.00	0.27
-0.10	0.02	26.26	0.00	0.00	0.00	0.00	0.34
0.00	0.03	26.43	0.00	0.00	0.00	0.00	0.40
0.10	0.04	26.59	0.00	0.00	0.00	0.00	0.46
0.20	0.05	26.77	0.00	0.00	0.00	0.00	0.53
0.30	0.06	26.95	0.00	0.00	0.00	0.00	0.64
0.40	0.08	27.12	0.00	0.00	0.00	0.01	0.71
0.50	0.10	27.27	0.00	0.00	0.00	0.08	0.80
0.60	0.13	27.45	0.00	0.00	0.00	0.17	0.91
0.70	0.16	27.61	0.00	0.00	0.00	0.25	0.99
0.80	0.20	27.80	0.00	0.00	0.00	0.34	1.00
0.90	0.24	27.97	0.00	0.00	0.07	0.42	1.00
1.00	0.29	28.14	0.00	0.00	0.14	0.52	1.00
1.10	0.33	28.31	0.00	0.00	0.22	0.60	1.00
1.20	0.38	28.48	0.00	0.00	0.29	0.69	1.00
1.30	0.42	28.64	0.00	0.00	0.37	0.78	1.00
1.40	0.47	28.83	0.00	0.02	0.45	0.87	1.00
1.50	0.51	28.99	0.00	0.08	0.52	0.96	1.00
1.60	0.55	29.16	0.00	0.14	0.59	1.00	1.00
1.70	0.59	29.33	0.00	0.19	0.67	1.00	1.00
1.80	0.62	29.50	0.00	0.25	0.75	1.00	1.00
1.90	0.65	29.68	0.00	0.31	0.82	1.00	1.00
2.00	0.68	29.85	0.00	0.37	0.90	1.00	1.00

Table 223: Call option prices for December Nino 3.4 SST conditioned on IRI ensemble forecasts released in April

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.01	22.64	0.00	0.00	0.00	0.00	0.00
-1.90	0.01	22.82	0.00	0.00	0.00	0.00	0.00
-1.80	0.01	23.01	0.00	0.00	0.00	0.00	0.00
-1.70	0.01	23.20	0.00	0.00	0.00	0.00	0.00
-1.60	0.01	23.38	0.00	0.00	0.00	0.00	0.00
-1.50	0.01	23.57	0.00	0.00	0.00	0.00	0.00
-1.40	0.01	23.75	0.00	0.00	0.00	0.00	0.00
-1.30	0.01	23.93	0.00	0.00	0.00	0.00	0.00
-1.20	0.01	24.12	0.00	0.00	0.00	0.00	0.00
-1.10	0.01	24.31	0.00	0.00	0.00	0.00	0.00
-1.00	0.01	24.50	0.00	0.00	0.00	0.00	0.00
-0.90	0.01	24.69	0.00	0.00	0.00	0.00	0.00
-0.80	0.01	24.87	0.00	0.00	0.00	0.00	0.03
-0.70	0.01	25.06	0.00	0.00	0.00	0.00	0.08
-0.60	0.01	25.23	0.00	0.00	0.00	0.00	0.08
-0.50	0.01	25.42	0.00	0.00	0.00	0.00	0.13
-0.40	0.01	25.60	0.00	0.00	0.00	0.00	0.17
-0.30	0.01	25.79	0.00	0.00	0.00	0.00	0.21
-0.20	0.02	25.98	0.00	0.00	0.00	0.00	0.29
-0.10	0.02	26.17	0.00	0.00	0.00	0.00	0.34
0.00	0.03	26.35	0.00	0.00	0.00	0.00	0.42
0.10	0.04	26.55	0.00	0.00	0.00	0.00	0.47
0.20	0.05	26.73	0.00	0.00	0.00	0.00	0.56
0.30	0.06	26.91	0.00	0.00	0.00	0.00	0.63
0.40	0.08	27.10	0.00	0.00	0.00	0.01	0.75
0.50	0.11	27.28	0.00	0.00	0.00	0.09	0.85
0.60	0.14	27.47	0.00	0.00	0.00	0.19	0.96
0.70	0.18	27.65	0.00	0.00	0.00	0.28	1.00
0.80	0.22	27.84	0.00	0.00	0.01	0.37	1.00
0.90	0.26	28.03	0.00	0.00	0.09	0.47	1.00
1.00	0.31	28.19	0.00	0.00	0.16	0.56	1.00
1.10	0.36	28.40	0.00	0.00	0.26	0.66	1.00
1.20	0.41	28.58	0.00	0.00	0.34	0.77	1.00
1.30	0.46	28.77	0.00	0.00	0.42	0.87	1.00
1.40	0.50	28.95	0.00	0.03	0.50	0.97	1.00
1.50	0.54	29.14	0.00	0.10	0.58	1.00	1.00
1.60	0.58	29.32	0.00	0.15	0.66	1.00	1.00
1.70	0.62	29.50	0.00	0.22	0.74	1.00	1.00
1.80	0.65	29.70	0.00	0.29	0.83	1.00	1.00
1.90	0.68	29.88	0.00	0.34	0.91	1.00	1.00
2.00	0.70	30.06	0.00	0.40	1.00	1.00	1.00

Table 224: Call option prices for December Nino 3.4 SST conditioned on IRI ensemble forecasts released in March

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.02	23.14	0.00	0.00	0.00	0.00	0.44
-1.90	0.03	23.31	0.00	0.00	0.00	0.00	0.45
-1.80	0.02	23.48	0.00	0.00	0.00	0.00	0.42
-1.70	0.02	23.66	0.00	0.00	0.00	0.00	0.42
-1.60	0.02	23.83	0.00	0.00	0.00	0.00	0.39
-1.50	0.02	23.99	0.00	0.00	0.00	0.00	0.38
-1.40	0.02	24.16	0.00	0.00	0.00	0.00	0.35
-1.30	0.02	24.34	0.00	0.00	0.00	0.00	0.35
-1.20	0.02	24.50	0.00	0.00	0.00	0.00	0.31
-1.10	0.02	24.68	0.00	0.00	0.00	0.00	0.31
-1.00	0.02	24.84	0.00	0.00	0.00	0.00	0.31
-0.90	0.02	25.00	0.00	0.00	0.00	0.00	0.29
-0.80	0.02	25.17	0.00	0.00	0.00	0.00	0.30
-0.70	0.02	25.35	0.00	0.00	0.00	0.00	0.32
-0.60	0.02	25.51	0.00	0.00	0.00	0.00	0.33
-0.50	0.02	25.68	0.00	0.00	0.00	0.00	0.35
-0.40	0.02	25.85	0.00	0.00	0.00	0.00	0.37
-0.30	0.03	26.02	0.00	0.00	0.00	0.00	0.40
-0.20	0.03	26.19	0.00	0.00	0.00	0.00	0.44
-0.10	0.04	26.36	0.00	0.00	0.00	0.00	0.50
0.00	0.04	26.52	0.00	0.00	0.00	0.00	0.56
0.10	0.05	26.69	0.00	0.00	0.00	0.00	0.62
0.20	0.07	26.86	0.00	0.00	0.00	0.00	0.71
0.30	0.09	27.04	0.00	0.00	0.00	0.01	0.82
0.40	0.11	27.21	0.00	0.00	0.00	0.10	0.90
0.50	0.14	27.37	0.00	0.00	0.00	0.18	1.00
0.60	0.18	27.55	0.00	0.00	0.00	0.28	1.00
0.70	0.21	27.71	0.00	0.00	0.00	0.36	1.00
0.80	0.25	27.88	0.00	0.00	0.02	0.46	1.00
0.90	0.29	28.04	0.00	0.00	0.10	0.55	1.00
1.00	0.34	28.22	0.00	0.00	0.18	0.65	1.00
1.10	0.38	28.39	0.00	0.00	0.25	0.75	1.00
1.20	0.42	28.55	0.00	0.00	0.33	0.85	1.00
1.30	0.46	28.73	0.00	0.00	0.40	0.95	1.00
1.40	0.49	28.90	0.00	0.00	0.48	1.00	1.00
1.50	0.52	29.07	0.00	0.00	0.55	1.00	1.00
1.60	0.55	29.23	0.00	0.00	0.63	1.00	1.00
1.70	0.58	29.41	0.00	0.05	0.70	1.00	1.00
1.80	0.60	29.58	0.00	0.10	0.78	1.00	1.00
1.90	0.63	29.74	0.00	0.13	0.85	1.00	1.00
2.00	0.65	29.91	0.00	0.18	0.93	1.00	1.00

Table 225: Call option prices for December Nino 3.4 SST conditioned on IRI ensemble forecasts released in February

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.15	25.23	0.00	0.00	0.00	0.00	1.00
-1.90	0.14	25.30	0.00	0.00	0.00	0.00	1.00
-1.80	0.14	25.34	0.00	0.00	0.00	0.00	1.00
-1.70	0.13	25.39	0.00	0.00	0.00	0.00	1.00
-1.60	0.13	25.46	0.00	0.00	0.00	0.00	1.00
-1.50	0.12	25.49	0.00	0.00	0.00	0.00	1.00
-1.40	0.11	25.54	0.00	0.00	0.00	0.00	1.00
-1.30	0.10	25.60	0.00	0.00	0.00	0.00	1.00
-1.20	0.10	25.64	0.00	0.00	0.00	0.00	1.00
-1.10	0.09	25.71	0.00	0.00	0.00	0.00	1.00
-1.00	0.09	25.75	0.00	0.00	0.00	0.00	1.00
-0.90	0.08	25.81	0.00	0.00	0.00	0.00	1.00
-0.80	0.07	25.85	0.00	0.00	0.00	0.00	1.00
-0.70	0.07	25.92	0.00	0.00	0.00	0.00	0.93
-0.60	0.06	25.97	0.00	0.00	0.00	0.00	0.86
-0.50	0.06	26.01	0.00	0.00	0.00	0.00	0.79
-0.40	0.05	26.07	0.00	0.00	0.00	0.00	0.73
-0.30	0.05	26.13	0.00	0.00	0.00	0.00	0.67
-0.20	0.05	26.17	0.00	0.00	0.00	0.00	0.67
-0.10	0.05	26.23	0.00	0.00	0.00	0.00	0.65
0.00	0.05	26.29	0.00	0.00	0.00	0.00	0.66
0.10	0.05	26.34	0.00	0.00	0.00	0.00	0.69
0.20	0.06	26.39	0.00	0.00	0.00	0.00	0.72
0.30	0.06	26.44	0.00	0.00	0.00	0.00	0.77
0.40	0.07	26.48	0.00	0.00	0.00	0.00	0.82
0.50	0.08	26.54	0.00	0.00	0.00	0.00	0.91
0.60	0.09	26.59	0.00	0.00	0.00	0.00	1.00
0.70	0.10	26.66	0.00	0.00	0.00	0.00	1.00
0.80	0.12	26.71	0.00	0.00	0.00	0.02	1.00
0.90	0.14	26.76	0.00	0.00	0.00	0.07	1.00
1.00	0.15	26.80	0.00	0.00	0.00	0.12	1.00
1.10	0.17	26.85	0.00	0.00	0.00	0.18	1.00
1.20	0.19	26.91	0.00	0.00	0.00	0.25	1.00
1.30	0.20	26.97	0.00	0.00	0.00	0.30	1.00
1.40	0.22	27.02	0.00	0.00	0.00	0.36	1.00
1.50	0.24	27.08	0.00	0.00	0.00	0.43	1.00
1.60	0.25	27.12	0.00	0.00	0.00	0.49	1.00
1.70	0.27	27.16	0.00	0.00	0.00	0.55	1.00
1.80	0.28	27.21	0.00	0.00	0.00	0.62	1.00
1.90	0.30	27.27	0.00	0.00	0.00	0.68	1.00
2.00	0.31	27.33	0.00	0.00	0.00	0.74	1.00

Table 226: Put option prices for December Nino 3.4 SST conditioned on IRI ensemble forecasts released in October

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.51	24.38	0.00	0.28	0.52	0.76	1.00
-1.90	0.48	24.49	0.00	0.24	0.47	0.71	1.00
-1.80	0.44	24.60	0.00	0.19	0.43	0.66	1.00
-1.70	0.40	24.70	0.00	0.15	0.38	0.61	1.00
-1.60	0.36	24.81	0.00	0.11	0.33	0.56	1.00
-1.50	0.32	24.91	0.00	0.07	0.29	0.51	0.99
-1.40	0.29	25.02	0.00	0.02	0.24	0.46	0.94
-1.30	0.25	25.13	0.00	0.00	0.19	0.41	0.89
-1.20	0.22	25.23	0.00	0.00	0.15	0.36	0.83
-1.10	0.18	25.34	0.00	0.00	0.10	0.31	0.77
-1.00	0.16	25.45	0.00	0.00	0.05	0.26	0.72
-0.90	0.13	25.55	0.00	0.00	0.00	0.21	0.68
-0.80	0.11	25.66	0.00	0.00	0.00	0.16	0.62
-0.70	0.09	25.77	0.00	0.00	0.00	0.11	0.56
-0.60	0.07	25.87	0.00	0.00	0.00	0.07	0.51
-0.50	0.05	25.97	0.00	0.00	0.00	0.02	0.46
-0.40	0.04	26.09	0.00	0.00	0.00	0.00	0.41
-0.30	0.03	26.19	0.00	0.00	0.00	0.00	0.36
-0.20	0.03	26.29	0.00	0.00	0.00	0.00	0.31
-0.10	0.02	26.40	0.00	0.00	0.00	0.00	0.27
0.00	0.02	26.50	0.00	0.00	0.00	0.00	0.22
0.10	0.01	26.61	0.00	0.00	0.00	0.00	0.17
0.20	0.01	26.72	0.00	0.00	0.00	0.00	0.13
0.30	0.01	26.83	0.00	0.00	0.00	0.00	0.07
0.40	0.01	26.93	0.00	0.00	0.00	0.00	0.03
0.50	0.00	27.03	0.00	0.00	0.00	0.00	0.00
0.60	0.00	27.14	0.00	0.00	0.00	0.00	0.00
0.70	0.00	27.26	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.35	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.46	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.57	0.00	0.00	0.00	0.00	0.00
1.10	0.00	27.68	0.00	0.00	0.00	0.00	0.00
1.20	0.00	27.79	0.00	0.00	0.00	0.00	0.00
1.30	0.00	27.89	0.00	0.00	0.00	0.00	0.00
1.40	0.00	27.99	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.10	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.20	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.31	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.42	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.53	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.63	0.00	0.00	0.00	0.00	0.00

Table 227: Put option prices for December Nino 3.4 SST conditioned on IRI ensemble forecasts released in September

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.60	24.11	0.00	0.35	0.64	0.93	1.00
-1.90	0.57	24.22	0.00	0.31	0.59	0.87	1.00
-1.80	0.53	24.34	0.00	0.26	0.54	0.82	1.00
-1.70	0.49	24.44	0.00	0.22	0.49	0.76	1.00
-1.60	0.45	24.57	0.00	0.17	0.44	0.71	1.00
-1.50	0.41	24.68	0.00	0.13	0.39	0.64	1.00
-1.40	0.37	24.80	0.00	0.08	0.33	0.59	1.00
-1.30	0.33	24.91	0.00	0.03	0.28	0.54	1.00
-1.20	0.30	25.02	0.00	0.00	0.24	0.49	1.00
-1.10	0.26	25.15	0.00	0.00	0.18	0.43	0.98
-1.00	0.23	25.25	0.00	0.00	0.14	0.38	0.92
-0.90	0.19	25.37	0.00	0.00	0.08	0.33	0.85
-0.80	0.16	25.48	0.00	0.00	0.04	0.27	0.78
-0.70	0.13	25.60	0.00	0.00	0.00	0.22	0.73
-0.60	0.11	25.71	0.00	0.00	0.00	0.16	0.67
-0.50	0.09	25.83	0.00	0.00	0.00	0.11	0.61
-0.40	0.07	25.94	0.00	0.00	0.00	0.06	0.56
-0.30	0.06	26.06	0.00	0.00	0.00	0.01	0.50
-0.20	0.05	26.17	0.00	0.00	0.00	0.00	0.44
-0.10	0.04	26.29	0.00	0.00	0.00	0.00	0.39
0.00	0.03	26.41	0.00	0.00	0.00	0.00	0.33
0.10	0.02	26.51	0.00	0.00	0.00	0.00	0.30
0.20	0.02	26.63	0.00	0.00	0.00	0.00	0.24
0.30	0.01	26.75	0.00	0.00	0.00	0.00	0.20
0.40	0.01	26.86	0.00	0.00	0.00	0.00	0.15
0.50	0.01	26.98	0.00	0.00	0.00	0.00	0.09
0.60	0.01	27.09	0.00	0.00	0.00	0.00	0.04
0.70	0.00	27.21	0.00	0.00	0.00	0.00	0.00
0.80	0.00	27.32	0.00	0.00	0.00	0.00	0.00
0.90	0.00	27.43	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.55	0.00	0.00	0.00	0.00	0.00
1.10	0.00	27.67	0.00	0.00	0.00	0.00	0.00
1.20	0.00	27.79	0.00	0.00	0.00	0.00	0.00
1.30	0.00	27.90	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.01	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.13	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.24	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.36	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.47	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.58	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.70	0.00	0.00	0.00	0.00	0.00

Table 228: Put option prices for December Nino 3.4 SST conditioned on IRI ensemble forecasts released in August

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.66	23.89	0.00	0.41	0.74	1.00	1.00
-1.90	0.62	24.01	0.00	0.36	0.68	1.00	1.00
-1.80	0.59	24.13	0.00	0.32	0.63	0.95	1.00
-1.70	0.55	24.27	0.00	0.26	0.58	0.88	1.00
-1.60	0.52	24.37	0.00	0.22	0.53	0.83	1.00
-1.50	0.48	24.50	0.00	0.17	0.47	0.77	1.00
-1.40	0.43	24.63	0.00	0.12	0.41	0.70	1.00
-1.30	0.40	24.74	0.00	0.07	0.36	0.65	1.00
-1.20	0.35	24.87	0.00	0.02	0.30	0.59	1.00
-1.10	0.32	24.99	0.00	0.00	0.25	0.53	1.00
-1.00	0.28	25.12	0.00	0.00	0.19	0.47	1.00
-0.90	0.24	25.23	0.00	0.00	0.14	0.41	1.00
-0.80	0.21	25.36	0.00	0.00	0.09	0.35	0.93
-0.70	0.18	25.48	0.00	0.00	0.04	0.30	0.86
-0.60	0.15	25.61	0.00	0.00	0.00	0.24	0.80
-0.50	0.12	25.73	0.00	0.00	0.00	0.18	0.73
-0.40	0.10	25.85	0.00	0.00	0.00	0.12	0.67
-0.30	0.08	25.98	0.00	0.00	0.00	0.07	0.61
-0.20	0.06	26.10	0.00	0.00	0.00	0.01	0.56
-0.10	0.05	26.22	0.00	0.00	0.00	0.00	0.50
0.00	0.04	26.35	0.00	0.00	0.00	0.00	0.44
0.10	0.03	26.46	0.00	0.00	0.00	0.00	0.37
0.20	0.02	26.59	0.00	0.00	0.00	0.00	0.32
0.30	0.02	26.71	0.00	0.00	0.00	0.00	0.28
0.40	0.01	26.83	0.00	0.00	0.00	0.00	0.22
0.50	0.01	26.95	0.00	0.00	0.00	0.00	0.17
0.60	0.01	27.07	0.00	0.00	0.00	0.00	0.12
0.70	0.01	27.20	0.00	0.00	0.00	0.00	0.08
0.80	0.01	27.32	0.00	0.00	0.00	0.00	0.02
0.90	0.00	27.44	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.57	0.00	0.00	0.00	0.00	0.00
1.10	0.00	27.69	0.00	0.00	0.00	0.00	0.00
1.20	0.00	27.82	0.00	0.00	0.00	0.00	0.00
1.30	0.00	27.94	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.05	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.18	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.30	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.43	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.54	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.66	0.00	0.00	0.00	0.00	0.00
2.00	0.00	28.79	0.00	0.00	0.00	0.00	0.00

Table 229: Put option prices for December Nino 3.4 SST conditioned on IRI ensemble forecasts released in July

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.70	23.64	0.00	0.46	0.84	1.00	1.00
-1.90	0.67	23.78	0.00	0.40	0.78	1.00	1.00
-1.80	0.64	23.91	0.00	0.35	0.73	1.00	1.00
-1.70	0.61	24.05	0.00	0.30	0.67	1.00	1.00
-1.60	0.57	24.18	0.00	0.25	0.61	0.97	1.00
-1.50	0.53	24.31	0.00	0.21	0.55	0.90	1.00
-1.40	0.49	24.45	0.00	0.15	0.49	0.83	1.00
-1.30	0.45	24.58	0.00	0.10	0.43	0.77	1.00
-1.20	0.41	24.71	0.00	0.05	0.38	0.70	1.00
-1.10	0.37	24.85	0.00	0.00	0.31	0.63	1.00
-1.00	0.33	24.99	0.00	0.00	0.25	0.57	1.00
-0.90	0.29	25.12	0.00	0.00	0.19	0.50	1.00
-0.80	0.25	25.26	0.00	0.00	0.13	0.43	1.00
-0.70	0.22	25.39	0.00	0.00	0.08	0.37	1.00
-0.60	0.18	25.52	0.00	0.00	0.02	0.31	0.95
-0.50	0.15	25.66	0.00	0.00	0.00	0.24	0.89
-0.40	0.13	25.79	0.00	0.00	0.00	0.18	0.81
-0.30	0.10	25.93	0.00	0.00	0.00	0.12	0.74
-0.20	0.08	26.06	0.00	0.00	0.00	0.06	0.67
-0.10	0.07	26.20	0.00	0.00	0.00	0.00	0.61
0.00	0.05	26.32	0.00	0.00	0.00	0.00	0.55
0.10	0.04	26.47	0.00	0.00	0.00	0.00	0.48
0.20	0.03	26.60	0.00	0.00	0.00	0.00	0.43
0.30	0.03	26.73	0.00	0.00	0.00	0.00	0.37
0.40	0.02	26.87	0.00	0.00	0.00	0.00	0.31
0.50	0.02	27.01	0.00	0.00	0.00	0.00	0.26
0.60	0.01	27.14	0.00	0.00	0.00	0.00	0.20
0.70	0.01	27.27	0.00	0.00	0.00	0.00	0.15
0.80	0.01	27.41	0.00	0.00	0.00	0.00	0.11
0.90	0.01	27.54	0.00	0.00	0.00	0.00	0.07
1.00	0.01	27.68	0.00	0.00	0.00	0.00	0.02
1.10	0.01	27.82	0.00	0.00	0.00	0.00	0.00
1.20	0.01	27.95	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.08	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.22	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.35	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.49	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.63	0.00	0.00	0.00	0.00	0.00
1.80	0.00	28.75	0.00	0.00	0.00	0.00	0.00
1.90	0.00	28.88	0.00	0.00	0.00	0.00	0.00
2.00	0.00	29.03	0.00	0.00	0.00	0.00	0.00

Table 230: Put option prices for December Nino 3.4 SST conditioned on IRI ensemble forecasts released in June

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.74	23.37	0.00	0.54	0.97	1.00	1.00
-1.90	0.72	23.52	0.00	0.48	0.90	1.00	1.00
-1.80	0.69	23.68	0.00	0.43	0.83	1.00	1.00
-1.70	0.66	23.83	0.00	0.37	0.77	1.00	1.00
-1.60	0.62	23.97	0.00	0.32	0.70	1.00	1.00
-1.50	0.58	24.13	0.00	0.26	0.63	1.00	1.00
-1.40	0.54	24.28	0.00	0.20	0.56	0.93	1.00
-1.30	0.50	24.44	0.00	0.14	0.50	0.85	1.00
-1.20	0.45	24.59	0.00	0.08	0.42	0.77	1.00
-1.10	0.41	24.74	0.00	0.03	0.36	0.70	1.00
-1.00	0.36	24.89	0.00	0.00	0.30	0.62	1.00
-0.90	0.32	25.04	0.00	0.00	0.23	0.55	1.00
-0.80	0.27	25.20	0.00	0.00	0.16	0.47	1.00
-0.70	0.23	25.34	0.00	0.00	0.10	0.40	1.00
-0.60	0.19	25.49	0.00	0.00	0.03	0.33	0.99
-0.50	0.16	25.65	0.00	0.00	0.00	0.25	0.91
-0.40	0.13	25.79	0.00	0.00	0.00	0.19	0.82
-0.30	0.10	25.96	0.00	0.00	0.00	0.11	0.73
-0.20	0.08	26.10	0.00	0.00	0.00	0.04	0.66
-0.10	0.06	26.26	0.00	0.00	0.00	0.00	0.58
0.00	0.05	26.41	0.00	0.00	0.00	0.00	0.51
0.10	0.04	26.55	0.00	0.00	0.00	0.00	0.45
0.20	0.03	26.71	0.00	0.00	0.00	0.00	0.38
0.30	0.02	26.86	0.00	0.00	0.00	0.00	0.31
0.40	0.02	27.01	0.00	0.00	0.00	0.00	0.25
0.50	0.01	27.17	0.00	0.00	0.00	0.00	0.18
0.60	0.01	27.32	0.00	0.00	0.00	0.00	0.14
0.70	0.01	27.48	0.00	0.00	0.00	0.00	0.08
0.80	0.01	27.63	0.00	0.00	0.00	0.00	0.04
0.90	0.01	27.78	0.00	0.00	0.00	0.00	0.00
1.00	0.00	27.93	0.00	0.00	0.00	0.00	0.00
1.10	0.00	28.08	0.00	0.00	0.00	0.00	0.00
1.20	0.00	28.23	0.00	0.00	0.00	0.00	0.00
1.30	0.00	28.37	0.00	0.00	0.00	0.00	0.00
1.40	0.00	28.54	0.00	0.00	0.00	0.00	0.00
1.50	0.00	28.68	0.00	0.00	0.00	0.00	0.00
1.60	0.00	28.83	0.00	0.00	0.00	0.00	0.00
1.70	0.00	28.99	0.00	0.00	0.00	0.00	0.00
1.80	0.00	29.14	0.00	0.00	0.00	0.00	0.00
1.90	0.00	29.30	0.00	0.00	0.00	0.00	0.00
2.00	0.00	29.45	0.00	0.00	0.00	0.00	0.00

Table 231: Put option prices for December Nino 3.4 SST conditioned on IRI ensemble forecasts released in May

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.75	23.01	0.00	0.55	1.00	1.00	1.00
-1.90	0.73	23.18	0.00	0.49	1.00	1.00	1.00
-1.80	0.71	23.35	0.00	0.44	0.98	1.00	1.00
-1.70	0.69	23.52	0.00	0.38	0.90	1.00	1.00
-1.60	0.66	23.70	0.00	0.32	0.82	1.00	1.00
-1.50	0.62	23.87	0.00	0.26	0.75	1.00	1.00
-1.40	0.59	24.03	0.00	0.20	0.67	1.00	1.00
-1.30	0.55	24.20	0.00	0.15	0.60	1.00	1.00
-1.20	0.51	24.38	0.00	0.09	0.52	0.96	1.00
-1.10	0.47	24.56	0.00	0.02	0.44	0.86	1.00
-1.00	0.42	24.73	0.00	0.00	0.37	0.78	1.00
-0.90	0.38	24.89	0.00	0.00	0.29	0.68	1.00
-0.80	0.33	25.07	0.00	0.00	0.22	0.59	1.00
-0.70	0.29	25.23	0.00	0.00	0.15	0.51	1.00
-0.60	0.24	25.40	0.00	0.00	0.07	0.42	1.00
-0.50	0.20	25.57	0.00	0.00	0.00	0.34	1.00
-0.40	0.16	25.75	0.00	0.00	0.00	0.25	1.00
-0.30	0.13	25.91	0.00	0.00	0.00	0.17	0.89
-0.20	0.10	26.09	0.00	0.00	0.00	0.09	0.79
-0.10	0.08	26.26	0.00	0.00	0.00	0.01	0.71
0.00	0.06	26.43	0.00	0.00	0.00	0.00	0.62
0.10	0.05	26.59	0.00	0.00	0.00	0.00	0.55
0.20	0.04	26.77	0.00	0.00	0.00	0.00	0.47
0.30	0.03	26.95	0.00	0.00	0.00	0.00	0.40
0.40	0.02	27.12	0.00	0.00	0.00	0.00	0.33
0.50	0.02	27.27	0.00	0.00	0.00	0.00	0.28
0.60	0.02	27.45	0.00	0.00	0.00	0.00	0.24
0.70	0.01	27.61	0.00	0.00	0.00	0.00	0.18
0.80	0.01	27.80	0.00	0.00	0.00	0.00	0.13
0.90	0.01	27.97	0.00	0.00	0.00	0.00	0.09
1.00	0.01	28.14	0.00	0.00	0.00	0.00	0.04
1.10	0.01	28.31	0.00	0.00	0.00	0.00	0.03
1.20	0.01	28.48	0.00	0.00	0.00	0.00	0.00
1.30	0.01	28.64	0.00	0.00	0.00	0.00	0.00
1.40	0.01	28.83	0.00	0.00	0.00	0.00	0.00
1.50	0.01	28.99	0.00	0.00	0.00	0.00	0.00
1.60	0.01	29.16	0.00	0.00	0.00	0.00	0.00
1.70	0.01	29.33	0.00	0.00	0.00	0.00	0.00
1.80	0.01	29.50	0.00	0.00	0.00	0.00	0.00
1.90	0.01	29.68	0.00	0.00	0.00	0.00	0.00
2.00	0.01	29.85	0.00	0.00	0.00	0.00	0.00

Table 232: Put option prices for December Nino 3.4 SST conditioned on IRI ensemble forecasts released in April

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.78	22.64	0.00	0.62	1.00	1.00	1.00
-1.90	0.76	22.82	0.00	0.57	1.00	1.00	1.00
-1.80	0.74	23.01	0.00	0.50	1.00	1.00	1.00
-1.70	0.72	23.20	0.00	0.45	1.00	1.00	1.00
-1.60	0.69	23.38	0.00	0.39	0.96	1.00	1.00
-1.50	0.67	23.57	0.00	0.33	0.88	1.00	1.00
-1.40	0.64	23.75	0.00	0.27	0.80	1.00	1.00
-1.30	0.61	23.93	0.00	0.21	0.72	1.00	1.00
-1.20	0.57	24.12	0.00	0.15	0.64	1.00	1.00
-1.10	0.53	24.31	0.00	0.08	0.56	1.00	1.00
-1.00	0.48	24.50	0.00	0.02	0.47	0.92	1.00
-0.90	0.44	24.69	0.00	0.00	0.39	0.81	1.00
-0.80	0.39	24.87	0.00	0.00	0.31	0.72	1.00
-0.70	0.34	25.06	0.00	0.00	0.23	0.62	1.00
-0.60	0.29	25.23	0.00	0.00	0.15	0.53	1.00
-0.50	0.24	25.42	0.00	0.00	0.06	0.43	1.00
-0.40	0.20	25.60	0.00	0.00	0.00	0.33	1.00
-0.30	0.16	25.79	0.00	0.00	0.00	0.24	0.99
-0.20	0.13	25.98	0.00	0.00	0.00	0.15	0.89
-0.10	0.10	26.17	0.00	0.00	0.00	0.06	0.78
0.00	0.07	26.35	0.00	0.00	0.00	0.00	0.68
0.10	0.05	26.55	0.00	0.00	0.00	0.00	0.59
0.20	0.04	26.73	0.00	0.00	0.00	0.00	0.51
0.30	0.03	26.91	0.00	0.00	0.00	0.00	0.44
0.40	0.03	27.10	0.00	0.00	0.00	0.00	0.37
0.50	0.02	27.28	0.00	0.00	0.00	0.00	0.32
0.60	0.02	27.47	0.00	0.00	0.00	0.00	0.26
0.70	0.01	27.65	0.00	0.00	0.00	0.00	0.20
0.80	0.01	27.84	0.00	0.00	0.00	0.00	0.16
0.90	0.01	28.03	0.00	0.00	0.00	0.00	0.12
1.00	0.01	28.19	0.00	0.00	0.00	0.00	0.10
1.10	0.01	28.40	0.00	0.00	0.00	0.00	0.05
1.20	0.01	28.58	0.00	0.00	0.00	0.00	0.05
1.30	0.01	28.77	0.00	0.00	0.00	0.00	0.01
1.40	0.01	28.95	0.00	0.00	0.00	0.00	0.00
1.50	0.01	29.14	0.00	0.00	0.00	0.00	0.00
1.60	0.01	29.32	0.00	0.00	0.00	0.00	0.00
1.70	0.01	29.50	0.00	0.00	0.00	0.00	0.00
1.80	0.01	29.70	0.00	0.00	0.00	0.00	0.00
1.90	0.01	29.88	0.00	0.00	0.00	0.00	0.00
2.00	0.01	30.06	0.00	0.00	0.00	0.00	0.00

Table 233: Put option prices for December Nino 3.4 SST conditioned on IRI ensemble forecasts released in March

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.68	23.14	0.00	0.29	1.00	1.00	1.00
-1.90	0.67	23.31	0.00	0.25	0.99	1.00	1.00
-1.80	0.65	23.48	0.00	0.20	0.92	1.00	1.00
-1.70	0.63	23.66	0.00	0.15	0.84	1.00	1.00
-1.60	0.60	23.83	0.00	0.11	0.76	1.00	1.00
-1.50	0.58	23.99	0.00	0.06	0.70	1.00	1.00
-1.40	0.55	24.16	0.00	0.01	0.63	1.00	1.00
-1.30	0.52	24.34	0.00	0.00	0.54	1.00	1.00
-1.20	0.48	24.50	0.00	0.00	0.47	1.00	1.00
-1.10	0.45	24.68	0.00	0.00	0.39	0.92	1.00
-1.00	0.41	24.84	0.00	0.00	0.32	0.82	1.00
-0.90	0.37	25.00	0.00	0.00	0.25	0.72	1.00
-0.80	0.33	25.17	0.00	0.00	0.17	0.63	1.00
-0.70	0.29	25.35	0.00	0.00	0.10	0.53	1.00
-0.60	0.25	25.51	0.00	0.00	0.02	0.44	1.00
-0.50	0.21	25.68	0.00	0.00	0.00	0.35	1.00
-0.40	0.17	25.85	0.00	0.00	0.00	0.26	1.00
-0.30	0.14	26.02	0.00	0.00	0.00	0.17	0.99
-0.20	0.11	26.19	0.00	0.00	0.00	0.09	0.88
-0.10	0.09	26.36	0.00	0.00	0.00	0.00	0.78
0.00	0.07	26.52	0.00	0.00	0.00	0.00	0.71
0.10	0.05	26.69	0.00	0.00	0.00	0.00	0.62
0.20	0.04	26.86	0.00	0.00	0.00	0.00	0.55
0.30	0.04	27.04	0.00	0.00	0.00	0.00	0.49
0.40	0.03	27.21	0.00	0.00	0.00	0.00	0.46
0.50	0.03	27.37	0.00	0.00	0.00	0.00	0.42
0.60	0.03	27.55	0.00	0.00	0.00	0.00	0.39
0.70	0.02	27.71	0.00	0.00	0.00	0.00	0.38
0.80	0.02	27.88	0.00	0.00	0.00	0.00	0.36
0.90	0.02	28.04	0.00	0.00	0.00	0.00	0.35
1.00	0.02	28.22	0.00	0.00	0.00	0.00	0.34
1.10	0.02	28.39	0.00	0.00	0.00	0.00	0.33
1.20	0.02	28.55	0.00	0.00	0.00	0.00	0.35
1.30	0.02	28.73	0.00	0.00	0.00	0.00	0.38
1.40	0.02	28.90	0.00	0.00	0.00	0.00	0.36
1.50	0.02	29.07	0.00	0.00	0.00	0.00	0.40
1.60	0.02	29.23	0.00	0.00	0.00	0.00	0.40
1.70	0.02	29.41	0.00	0.00	0.00	0.00	0.44
1.80	0.03	29.58	0.00	0.00	0.00	0.00	0.43
1.90	0.03	29.74	0.00	0.00	0.00	0.00	0.46
2.00	0.03	29.91	0.00	0.00	0.00	0.00	0.46

Table 234: Put option prices for December Nino 3.4 SST conditioned on IRI ensemble forecasts released in February

IRI anom	price per USD	E[SST]	2.5^{th} q	25^{th} q	50^{th} q	75^{th} q	97.5^{th} q
-2.00	0.41	25.23	0.00	0.00	0.15	1.00	1.00
-1.90	0.40	25.30	0.00	0.00	0.12	1.00	1.00
-1.80	0.39	25.34	0.00	0.00	0.11	1.00	1.00
-1.70	0.38	25.39	0.00	0.00	0.08	0.97	1.00
-1.60	0.36	25.46	0.00	0.00	0.05	0.90	1.00
-1.50	0.35	25.49	0.00	0.00	0.04	0.85	1.00
-1.40	0.34	25.54	0.00	0.00	0.02	0.78	1.00
-1.30	0.32	25.60	0.00	0.00	0.00	0.72	1.00
-1.20	0.31	25.64	0.00	0.00	0.00	0.67	1.00
-1.10	0.29	25.71	0.00	0.00	0.00	0.60	1.00
-1.00	0.28	25.75	0.00	0.00	0.00	0.54	1.00
-0.90	0.26	25.81	0.00	0.00	0.00	0.48	1.00
-0.80	0.24	25.85	0.00	0.00	0.00	0.43	1.00
-0.70	0.22	25.92	0.00	0.00	0.00	0.37	1.00
-0.60	0.20	25.97	0.00	0.00	0.00	0.32	1.00
-0.50	0.18	26.01	0.00	0.00	0.00	0.27	1.00
-0.40	0.16	26.07	0.00	0.00	0.00	0.22	1.00
-0.30	0.15	26.13	0.00	0.00	0.00	0.18	1.00
-0.20	0.13	26.17	0.00	0.00	0.00	0.14	1.00
-0.10	0.12	26.23	0.00	0.00	0.00	0.10	1.00
0.00	0.11	26.29	0.00	0.00	0.00	0.08	0.97
0.10	0.11	26.34	0.00	0.00	0.00	0.05	0.96
0.20	0.10	26.39	0.00	0.00	0.00	0.03	0.96
0.30	0.10	26.44	0.00	0.00	0.00	0.02	0.98
0.40	0.10	26.48	0.00	0.00	0.00	0.01	0.99
0.50	0.10	26.54	0.00	0.00	0.00	0.01	1.00
0.60	0.11	26.59	0.00	0.00	0.00	0.01	1.00
0.70	0.11	26.66	0.00	0.00	0.00	0.00	1.00
0.80	0.12	26.71	0.00	0.00	0.00	0.00	1.00
0.90	0.12	26.76	0.00	0.00	0.00	0.01	1.00
1.00	0.13	26.80	0.00	0.00	0.00	0.03	1.00
1.10	0.14	26.85	0.00	0.00	0.00	0.04	1.00
1.20	0.15	26.91	0.00	0.00	0.00	0.06	1.00
1.30	0.15	26.97	0.00	0.00	0.00	0.05	1.00
1.40	0.16	27.02	0.00	0.00	0.00	0.08	1.00
1.50	0.16	27.08	0.00	0.00	0.00	0.08	1.00
1.60	0.17	27.12	0.00	0.00	0.00	0.10	1.00
1.70	0.17	27.16	0.00	0.00	0.00	0.12	1.00
1.80	0.18	27.21	0.00	0.00	0.00	0.14	1.00
1.90	0.19	27.27	0.00	0.00	0.00	0.16	1.00
2.00	0.19	27.33	0.00	0.00	0.00	0.17	1.00

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