



2013

Financial Inclusion and Natural Disasters

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FINANCIAL INCLUSION AND NATURAL DISASTERS

Dissertation

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

By
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ABSTRACT OF DISSERTATION

FINANCIAL INCLUSION AND NATURAL DISASTERS

This dissertation explores the implications of natural disaster risk for access to financial services, especially credit. Its results show that disasters can dramatically undermine the ability of financial intermediaries (FIs) to lend after an event, increasing the cost of the disaster and delaying recovery. Moreover, the risk of natural disasters discourages investment in vulnerable regions and economic sectors and so slows economic development. Financial risk transfer mechanisms such as insurance can help maintain lending following an event. While many international development projects have targeted disaster insurance markets to households, managing disaster-related credit risk may be done more effectively through insurance products for FIs. Additionally, prudential supervision and the credit risk rating methods of investors in developing and emerging economies are dominated by developed country standards that overlook natural disaster risks. Public and private interests align in the need to tailor such standards and so enhance the effectiveness with which vulnerable FIs manage disaster risk.

KEYWORDS: Inclusive Finance, Natural Disasters, Risk and Insurance, International Development, Banking Policy

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FINANCIAL INCLUSION AND NATURAL DISASTERS

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To Brittany Collier for your consistent and generous kindness, love, and support.

To Jane Collier for making my life brighter. You were born two days before my defense and, ever since, have made the world spin faster.

To Robert and Joan Collier for modeling how to live with love, wisdom, compassion, and integrity.

ACKNOWLEDGEMENTS

The following dissertation, while an individual work, benefited from the insights and direction of several people. First, I want to acknowledge Jerry Skees, Dissertation Co-chair, adviser, boss, and friend. Jerry, you have an unmatched ability to see the next step first. I will always be grateful to you for taking a chance on me and helping me flourish. Also, Mario Miranda, Dissertation Co-chair, enhanced the technical quality of this work. Mario, you made the dissertation more interesting and fun, thanks. Finally, I wish to thank the complete Dissertation Committee, and outside reader, respectively: Leigh Maynard, Paul Shea, and Dwight Denison. Each individual provided insights that guided and challenged my thinking, substantially improving the finished product.

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Chapter 1. Introduction

1.1. Introduction and objectives

This dissertation is part of my broader research program regarding the effects of natural disasters on development-oriented investment in developing and emerging economies. Specifically, the dissertation explores the implications of natural disaster risk for access to financial services, especially credit. Its results show that disasters can dramatically undermine the ability of financial intermediaries (FIs) to lend after an event, increasing the cost of the disaster and delaying recovery. Moreover, the risk of natural disasters discourages investment in vulnerable regions and economic sectors and so slows economic development. Financial risk transfer mechanisms such as insurance can help maintain lending following an event. While many international development projects have targeted disaster insurance markets to households, managing disaster-related credit risk may be done more effectively through insurance products for FIs. Additionally, prudential supervision and the credit risk rating methods of investors in developing and emerging economies are dominated by developed country standards that overlook natural disaster risks. Public and private interests align in the need to tailor such standards and so enhance the effectiveness with which vulnerable FIs manage disaster risk. The dissertation is organized around four objectives.

Objective 1: Identify the challenges that natural disasters create for FIs because of their important role in channelling investments.

Natural disasters challenge development in developing and emerging economies. A variety of microeconomic and institutional foundations may explain the increased vulnerability of these economies. First, they tend to participate in at-risk sectors such as agriculture and tourism (Loayza et al., 2012). Agriculture accounts for 22% of GDP and 53% of the labor force for countries ranked “low” on the United Nations Human Development Index (HDI), compared to 2% of GDP and 5% of the labor force for “very high” HDI countries.¹ Second,

¹From World Bank (2012) and HDI (2012) data

due to limited access to financial risk management mechanisms, especially insurance, households tend to be more interdependent, especially in rural communities (Townsend, 1994). Some communities develop complex risk sharing arrangements that facilitate management of idiosyncratic risks (Dercon, 2002; Fafchamps and Lund, 2003). These arrangements tend to break down during natural disasters as many individuals in the community need help concurrently (Dercon, 2004; Townsend, 1994). Third, many cities in developing and emerging economies are struggling to accommodate rapid urbanization, leading the urban poor to settle undesirable land such as in low-lying areas and steep hillsides (Stern, 2007). These communities are also vulnerable due to members residing in less durable structures as well as a lack of public sanitation and other services. Fourth, the outreach of social safety nets is often limited. While international aid agencies partially offset insufficient developing country relief budgets, aid can be slow. For example, Lentz et al. (2013) estimate emergency food aid shipments arrive over five months, on average, after aid is requested. Finally, not only are these countries more vulnerable to disaster events but severe weather tends to occur more frequently. Many developing countries are in tropical regions, which experience higher temperatures but also greater rainfall variability (Brown and Lall, 2006). Rainfall is often concentrated in a single season, increasing the risk of drought and excess rain and flooding.

Macroeconomic research generally suggests that severe natural disasters negatively affect growth. Previous literature reports conflicting results, that disasters have negative (Rasmussen, 2004), positive (Skidmore and Toya, 2002), or neutral (Cavallo et al., 2010) effects on growth; however, recent studies use more detailed datasets to disaggregate effects and explain these results (Loayza et al., 2012; von Peter et al., 2012; Noy, 2009). For example, Loayza et al. (2012) demonstrate that individual economic sectors differ regarding their vulnerability to natural disasters. Agricultural growth is more vulnerable to drought; industrial growth to flood. More generally, this literature identifies two offsetting effects of disasters on growth. First, disasters reduce the stock of productive capital and so reduce total output. Following neoclassical models, the marginal product of capital increases as its absolute level falls. This dynamic leads to the second effect: reinvestment after the event stimulates the economy and generates higher returns. Noy (2009) finds that the net effect of a disaster is significantly determined by the ability of an economy to mobilize reinvestment. This reinvestment capacity is positively associated with literacy rates, income per capita, openness to trade, government size, and institutional quality. Thus, recent research sug-

gests that severe disasters tend to negatively affect growth because losses exceed a country's capacity to reconstruct (Loayza et al., 2012; von Peter et al., 2012; Hallegatte et al., 2007). This research also demonstrates that the negative consequences of disasters are greater in developing and emerging economies, likely because of 1) increased vulnerability as described above, and 2) a limited capacity to mobilize reinvestment.

These results suggest that the resilience of investment channels to natural disasters may have significant implications for the effects of these events on an economy. Macroeconomic evidence from Noy (2009) indicates that while domestic stock market capitalization does not improve disaster recovery, domestic credit markets do. Thus, mobilizing investments for micro, small, and medium enterprises may be particularly important for recovery. A clearer understanding of microeconomic mechanisms that drive these macroeconomic results is needed.

Objective 2: Evaluate the potential of insurance to reduce disaster-related disruptions in credit provision.

Not only do natural disaster events reduce growth, but the *risk* of these events delays development. For example, Skidmore and Toya (2002) note that disaster vulnerability motivates economies to substitute away from physical capital investments toward human capital. Given the Cobb-Douglas production functions typically used in production and growth theory (e.g., $f = k^\alpha h^\beta$ where k is physical capital, h human capital, f total output, and $\alpha + \beta \leq 1$), constraints on one factor will tend to reduce overall productivity. At the producer level, disaster risk has also been shown to lead to production decisions that reduce overall output. For example, Rosenzweig (1992) demonstrates that lower risk strategies reduced farmers' expected returns by one third in Andhra Pradesh. Disaster risk reduces credit investment in vulnerable regions and sectors such as agriculture, as well (Boucher et al., 2008; Hazell et al., 1985). Socially oriented investments intended to increase financial inclusion have increased exponentially in recent years (Consultative Group to Assist the Poor, CGAP, 2011b); however, vulnerable regions and sectors often remain excluded.

Risk transfer mechanisms such as insurance may be particularly helpful in facilitating access to credit for vulnerable groups (Skees et al., 2007). While a variety of risk management strategies, such as diversification and holding excess reserves, can reduce disaster risk, financial mechanisms such as insurance seem particularly well-suited to complement credit. Moreover, von Peter et al. (2012) show that it is uninsured losses that lead to negative

growth after a disaster. Perhaps because insurance facilitates reconstruction, well-insured disasters neutrally or even positively affect growth. Thus, insurance may play a dual role by both reducing disaster losses for the insured and increasing investment opportunities and output more generally.

Objective 3: Compare the developmental implications of designing insurance products for households versus FIs to manage disaster-related credit risk.

The international development community has invested a great deal in testing the potential of insurance markets to address disaster risks in developing and emerging economies (Miranda and Farrin, 2012; Murphy et al., 2011). These projects have primarily used index insurance, a type of insurance that bases payments on an objective measure of a disaster (e.g., weather station data to estimate drought) and so can be used in a variety of contexts where traditional insurance is infeasible. Insurance for households predominate donor-funded index insurance projects, and some have tested bundling insurance with credit contracts to address disaster-related credit risk (Carter, 2009; Global Facility for Disaster Reduction and Recovery, GFDRR, 2011).

Experience suggests that many institutional constraints and high costs challenge the development of insurance markets for households. The costs include household-level capacity building and delivery of small-value insurance products. With some exceptions, the scalability and sustainability of household-level index insurance projects are unclear; many markets will not survive when donor support ends. Moreover, emphasis has been placed on index insurance as a developing country proxy for developed country agricultural insurance. That model focuses on protecting insureds from yield risk associated with a single crop in a single season, but often ignores what the growth literature indicates is the primary economic consequence of natural disasters, physical capital losses. The focus on income for specific crops is over emphasized and has limited the relevance of index insurance for managing disaster risks, leading to serious questions regarding its value for development (Binswanger-Mkhize, 2012). These observations have motivated some researchers to rethink their approach in recent years by orienting it toward conditions that lead to viable markets (e.g., Miranda and Gonzalez-Vega, 2011; Skees and Barnett, 2006; Skees, 2008)

Because of the flexibility of index insurance, these contracts can be used directly by FIs rather than their borrowing households and firms. Targeting disaster insurance to FIs has the potential to overcome the challenges to private-sector viability described above.

Insurance for FIs would not address many of the economic hardships that households and firms experience because of a disaster. Still, insurance that manages the disaster-related loan losses experienced by FIs may preserve their ability to provide credit to these households and firms after a disaster. Because lower income households and small firms are often the targeted beneficiaries of development projects, a better understanding of the effects of lender-level disaster insurance on credit markets is needed.

Objective 4: Evaluate the incentives of FIs to manage disaster risk in socially desirable ways.

FI resilience has positive public externalities; likewise, FI failure can adversely affect depositors, create contagion in the financial sector, and reduce economic productivity. FIs also tend to be highly leveraged firms, increasing incentives of liability holders to manage large losses. As a result, the priorities and approaches FIs adopt for managing systemic risk are largely influenced by regulating supervisors and FI investors. Regulating supervisors impose prudential standards to align the incentives of FIs with those of the public (Basel Committee on Banking Supervision, BCBS, 2006, 2011b). While the financial sectors of developing and emerging economies may face quite different risks, these economies tend to adopt the Basel Accords, international banking standards developed for the largest banks in developed countries (Financial Stability Institute, 2010). Those standards focus on the role of large FIs in the global economy and so tend to overlook risks with regional effects such as natural disasters. Similarly, credit rating agencies and investors often use credit risk protocols designed for developed country FIs (e.g., those from Standard & Poor's and Moody's) to evaluate FIs in developing and emerging economies, despite differences in the risks faced by these firms. This practice of adopting developed country approaches would seem to create a paradigm in vulnerable developing and emerging economies where managing disaster-related credit risk has private and public benefits but FIs are not incentivized to do so.

1.2. Methodology

Addressing these objectives requires a combination of theoretical and empirical research and policy analysis. The theoretical research involves two elements. First, I intend to specify a dynamic model of a representative FI that allows for examining FI performance under risk

while simulating natural disasters. This model is intended to identify a mechanism that helps explain the empirical macroeconomic results described above. Second, I intend to apply neoclassical growth models to evaluate the contribution to development of alternative insurance products. Regarding policy analysis, I intend to review international banking standards and research on how it is applied in developing and emerging economies to evaluate its implications for managing disaster risk. If possible, this analysis will also include evaluation of private sector monitoring mechanisms such as credit risk rating methodologies; however, access to private sector mechanisms is likely more difficult to acquire.

The empirical research in this dissertation draws heavily from my field work in northern Peru where severe El Niño events cause torrential rains and flooding. Along the Pacific coast, northern Peru is arid with good soils and irrigated agriculture, making it one of the most productive agricultural regions in Peru, employing 37% of the workforce, which almost exclusively works on small farms of less than 10 hectares (Instituto Nacional de Estadística e Informática, 2007; Trivelli, 2006). Moving from the coast eastward, the region is dominated by tree crops such as coffee and cocoa as the terrain changes quickly to semi-tropical small mountains. Farther east are the high Andes where agriculture supports local consumption. Fifty-four percent of the population in Piura, a large region in the north, is at or below the poverty line (Instituto Nacional de Estadística e Informática, 2007). Credit is an important component of livelihood enhancement for households in the region, and organizations providing micro- and small-enterprise loans have grown significantly in recent years. For example, the loan portfolio of Caja Piura, one of the largest municipal banks in the region, grew from USD 3 million in January 1994 to USD 566 million in December 2012.² During the last severe El Niño, which occurred in 1998, rainfall in northern Peru was roughly forty times normal levels for the months January to April (Skees and Murphy, 2009). As a result, agricultural production declined by 30 percent (Cruzado Silveri, 1999). Extreme flooding damaged or destroyed roads, bridges, reservoirs, irrigation systems, and other public infrastructure, disrupting trade and creating additional losses for enterprises in the region. This diverse set of consequences translated into poor loan performance for FIs.

²Data from the Peruvian banking supervisor, available at www.sbs.gob.pe

1.3. Structure

The dissertation is structured as three papers. The first paper, Chapter 2, pursues the objective of identifying the challenges that natural disasters create for FIs. It models the disruptions in credit markets created by disaster-related loan losses that constrain FIs. In this paper, I develop a dynamic, stochastic model to evaluate FI performance under risk and simulate disaster events. Investors and regulating supervisors monitor FIs using minimum capital requirements. These standards require that the size of risky investments such as loans held by an FI do not exceed its equity holdings by a certain factor. Minimum capital requirements have the effect of limiting the size of an FI based on its stock of equity. The model is calibrated for a representative Peruvian FI that specializes in microfinance and is vulnerable to severe El Niño. Using the results from Collier (2010) as a reference, I update exposure estimates for this FI, developing and implementing a survey instrument administered to its credit risk managers operating in the vulnerable region. Solving the specified model requires numerical techniques. Its results show that loan losses erode the equity of an FI and because of minimum capital requirements, FIs contract credit after a natural disaster. Because of the risk of falling below capital minimum requirements, FIs hold a capital buffer in excess of the required minimum. This buffer has the result of reducing the level of loans supplied under non-disaster conditions.

Chapter 2 also addresses the second objective of the dissertation by modeling the effect of insuring against severe El Niño on FI operations. By protecting the FI, the insurance motivates it to reduce its capital buffer and so increase lending during non-disaster conditions. When a disaster leads to loan losses, an insurance payment protects the equity of the FI and so maintains the provision of credit after the event. This result provides additional insight into the macroeconomic findings by Noy (2009) and von Peter et al. (2012) and seems to suggest that if FIs manage disaster-related loan losses through insurance, it is likely to reduce the total cost of a disaster by enhancing an economy's reinvestment capacity.

Chapter 3, the second paper, addresses the third objective of the dissertation, comparing the implications for development of managing disaster-related credit risk using products designed for households versus those for FIs. I use a neoclassical growth model as a foundation for evaluating household cashflows under different product structures. This paper considers several scenarios. The first is that financial markets are unconstrained and FIs can access additional investments if borrowers fail to repay. Under this condition, FIs can

fully manage disaster-related credit risk through access to international markets. Insurance does not add value. In the second scenario, FIs face high short-term borrowing costs so that if households must delay loan repayment, FIs incur additional costs of meeting their own liabilities. Under this condition, insurance reduces the cost of providing credit to borrowers vulnerable to disasters, lowering borrower interest rates. This benefit is the same regardless of whether insurance is designed to be purchased by borrowing households or the FI. In the third scenario, I formulate the insurance product as index insurance and so introduce basis risk — the risk that the measurement of the disasters will differ from that experienced by the insured. Products designed for borrowing households would use the weather station closest to their property as their index while FIs would use a network of weather stations weighted based on their loan allocations. Using properties of estimators, I show that the FI index has lower basis risk than the index for households. Reducing basis risk reduces the cost of the event for households so the insurance for FIs, who pass costs and benefits to households through the loan contract, is preferred. Fourth and finally, I evaluate a condition of limited default in which the disaster causes only a portion of vulnerable borrowers to default, but which vulnerable borrowers will default is not known *ex ante*. In some index insurance pilots, microfinance institutions require all borrowers to insure. Under this scenario, insurance designed for borrowing households will tend to over insure credit losses from the disaster. Model comparisons show that insurance for FIs reduces the cost of managing disaster-related credit risk for households when compared to household-level insurance.

Chapter 4, the third paper, addresses the fourth objective of the dissertation, evaluating the incentives of FIs to manage disaster risks. This paper describes the evolution of investment in inclusive finance — financial services targeted at groups traditionally underserved by financial markets, such as the poor, agricultural producers, women, the disabled, etc. — and demonstrates that developing countries, the primary focus of financial inclusion, are most vulnerable to natural disasters, making disaster risk an important issue for sustainable development. The paper also reviews international banking standards such as the Basel Accords, their intended purpose, and how they are implemented. It explores the question of how well these standards protect FIs specializing in inclusive finance from the systemic risks to which they are exposed, especially natural disaster risk. By relying so heavily on minimum capital requirements, international standards may actually exacerbate disaster losses by motivating FIs to contract lending after the event. The paper also examines the

determinants of capital reserves using data on over 900 FIs specializing in inclusive finance. Paper results show theoretically and empirically that prudential standards do not tend to be sensitive to risks faced by these FIs. Vulnerable developing and emerging economies would likely benefit from public and private banking policies that recognize a broader set of approaches to managing natural disaster risk, including ones that are less disruptive to the provision of credit. The paper concludes with specific recommendations for investors and regulating supervisors.

Chapter 2. Natural Disasters and Credit Supply Shocks

2.1. Introduction

This paper explores the consequences of natural disaster risk for financial intermediaries (FIs), particularly in the context of developing and emerging economies where financial markets are underdeveloped. We model a representative, dynamically optimizing lender managing a stock of equity capital to maximize dividend payments to its shareholders. The model is calibrated using data from a Peruvian FI that specializes in microfinance and is vulnerable to the risk of severe El Niño, an event that brings torrential rains and flooding to northern Peru. The model demonstrates that loan losses from the event destroy the capital of the lender. Following the disaster, the lender reduces loan allocations, bringing them in line with a smaller capital base but also limiting access to credit for borrowing households and firms. Retained earnings allow the lender to recover after several periods, returning to pre-disaster levels of lending. Because of the business disruptions created by disaster losses, the risk of these events leads the lender to maintain capital reserves in excess of the amount required by the regulating supervisor. This strategy has the effect of reducing the supply of credit in non-disaster conditions and limiting profits and growth of the FI.

Additionally, we consider an insurance-like mechanism that would transfer the disaster risk of the FI. FIs in Peru can now purchase El Niño insurance, and we evaluate this mechanism in the model calibrated for the Peruvian microfinance intermediary. Results indicate that, when a severe El Niño occurs, insurance payouts offset capital losses. By protecting the lender's equity capital, insurance prevents the credit contraction described above. As a result of managing its disaster risk with insurance, the lender maintains a lower capital ratio, increasing its loan allocations. Insurance against natural disasters seems to facilitate the lender's objective of maximizing shareholder dividends. It also leads to the desirable public policy outcome of more consistent access to credit. Based on this research, a large microfinance intermediary in Peru has insured against El Niño for the past two years.

2.1.1. Background and literature review

A substantial body of theoretical and empirical research demonstrates that the financial system can play an important role in promoting economic growth (e.g., King and Levine, 1993). These benefits are seen across stages of development and firm size (Alfaro et al., 2004; Beck and Levine, 2004; Beck et al., 2008). For example, Fafchamps and Schündeln (2013) demonstrate that credit increases firm growth and firm entry and reduces the likelihood of firm exit in Morocco. Moreover, while microfinance will not solve the challenges of poverty and inequality, access to financial services for poor households and other underserved markets also seem to contribute to productivity and other socially desirable outcomes (Banerjee et al., 2009; Bauchet et al., 2011; Kaboski and Townsend, 2011). Thus, this paper is built on the premise that broad, accessible credit markets benefit communities and their economies and that increasing the resilience of these markets against systemic shocks is in the interest of both public and private stakeholders.

Capital reserves and systemic risk

In banking, capital is the value of the FI held by its long-term investors with subordinated claims. This capital is primarily shareholder equity; however, international banking standards identify several other forms such as long-term subordinated debt (Basel Committee on Banking Supervision, BCBS, 2011b; 2006).

Capital is an important concept in the context of managing systemic risk as it identifies the losses an FI can sustain and remain solvent. Central to prudential banking standards are minimum capital requirements, a rule that the ratio of capital to risky investments such as loans cannot fall below a certain level (e.g., 8%). This rule has the effect of limiting the size of an FI based on its stock of capital. Unregulated or limitedly regulated FIs may face similar requirements from their liability holders. FIs operating with low capital ratios will tend to pay high borrowing rates or may be refused credit altogether. As a point of reference, 44% of FIs reporting to MIX Market (2013), an international database of FIs offering microfinance, are not regulated.

Capital is a binding constraint for many FIs in developing and emerging economies. Socially oriented investing has rapidly increased access to funds for FIs targeting underserved markets. For example, cross-border investments in financial inclusion grew from about \$2 billion in 2005 to \$25 billion in 2011 (Consultative Group to Assist the Poor,

CGAP, 2012). Yet, these investors are primarily holding liabilities and only willing to invest equity in the largest, most secure FIs (MicroRate, 2011). To grow, FIs that cannot attract new capital must reinvest income in the firm.

Systemic credit risks are those events which create repayment problems for many borrowers concurrently, such as a macroeconomic crisis. Systemic events create loan losses that erode the capital of FIs. Peek and Rosengren (1995) use a static model to consider the response of an FI when its capital ratio falls below some minimal threshold. They demonstrate that as the capital constraint becomes binding, the FI must reduce the size of its assets and liabilities. In a dynamic context, FIs experiencing a low capital ratio will tend to originate fewer new loans. Reducing the level of loans originated reduces income, slowing recovery. This dynamic leads Van den Heuvel (2009) to conclude that: “The main cost of under-capitalization to the bank is thus that it must forgo profitable lending opportunities.”

Capital supervision and its opportunity cost

Prudential standards relying on capital requirements can create moral hazard, depending on how they are enforced. Calem and Rob (1999) describe a U-shaped pattern in risk taking where FIs operating close to the specified minimum capital requirements take less risk. Those operating with high capital ratios have incentives to increase risk taking which can improve returns as their excess capital insulates them from insolvency. FIs that are severely undercapitalized engage in the highest level of risk taking as the probability of insolvency is higher for these FIs so a high risk strategy may be the best possibility for recapitalizing.

This moral hazard motivates regulating supervisors to impose progressive penalties, increasing as the stock of FI capital falls farther below the minimum capital requirement. For example in the United States, supervisors impose “prompt corrective action,” a set of increasingly invasive responses to undercapitalization. FIs operating just below the minimum capital requirement are required, among other things, to provide a capital restoration plan and limit their asset growth. For *significantly* undercapitalized FIs, supervisors may also limit payments of dividends and management fees, dismiss directors and senior executives, and require the FI to divest from holdings in risky subsidiaries. For *critically* undercapitalized FIs, supervisors may also restrict payments on subordinated debt and place the FI under the management of another institution such as the Federal Deposit Insurance Corporation (United States Office of the Law Revision Counsel, 2013).

Given the threat of supervisory intervention, FIs often hold capital reserves in excess of minimum requirements. For example, Rime (2001) and Ediz et al. (1998) show that banks operating in Switzerland and the United Kingdom, respectively, actively managed their capital to remain above the regulated minimum. The amount held above the regulated minimum is related to the level of risk under which FIs operate. These findings imply that FIs are holding additional capital to minimizing the costly risk of supervisory intervention that may emerge from a systemic event. This strategy comes at the opportunity cost of reducing loan allocations and so reducing income.

Natural disasters as systemic shocks

International banking standards, including those for minimum capital requirements, focus on the role of large, international banks in the global economy. While these standards are written for the biggest banks in developed countries, they are often used to regulate a wide variety of FIs across diverse jurisdictions. For example, a survey of banking supervisors in 2010 indicated that 84% of jurisdictions had implemented or planned to implement Basel II, the contemporary version of international banking standards (133 jurisdictions completed the survey, Financial Stability Institute, 2010).

Because of their focus, these standards sometimes overlook important systemic risks affecting certain types of FIs and jurisdictions. We believe this is the case regarding natural disaster risks in the financial sectors of many developing and emerging economies. These economies are more vulnerable to disasters for a variety of reasons, including greater participation in vulnerable sectors such as agriculture and tourism, lower insurance penetration, less resilient public and private infrastructure, and more limited public safety nets.

Macroeconomic research generally suggests that severe natural disasters negatively affect growth in developing and emerging economies. Previous literature reports conflicting results, that disasters have negative (Rasmussen, 2004), positive (Skidmore and Toya, 2002), or neutral (Cavallo et al., 2010) effects on growth; however, recent studies use more detailed datasets to disaggregate effects and explain these results (Loayza et al., 2012; Noy, 2009; von Peter et al., 2012). For example, Loayza et al. (2012) demonstrate that economic sectors differ regarding the types of disasters to which they are vulnerable. Agricultural growth is more vulnerable to drought; industrial growth to flood. More generally, this literature identifies two offsetting effects of disasters on growth. First, disasters reduce the stock of productive capital and so reduce total output. Following neoclassical models, the marginal

product of capital increases as its absolute level falls. This dynamic leads to the second effect: reinvestment after the event stimulates the economy and generates higher returns. Noy (2009) notes that the net effect of a disaster is significantly affected by the ability of an economy to mobilize reinvestment. This capacity to mobilize investment is positively associated with the size of domestic credit markets, literacy rates, income per capita, openness to trade, government size, and institutional quality. Thus, recent research suggests that severe disasters tend to negatively affect growth because losses exceed a country's reconstruction capacity (Hallegatte et al., 2007; Loayza et al., 2012; von Peter et al., 2012). This research also demonstrates that the negative consequences of disasters are greater in developing and emerging economies, likely because of 1) increased vulnerability as described above, and 2) a limited capacity to mobilize reinvestment.

Given the importance of FIs in allocating investments, a clearer understanding of the effects of disasters on these institutions is needed. Little is known about disaster-related credit risk, especially in developing and emerging economies. Following this logic, this paper demonstrates the significant challenges that disasters create for FIs and illustrates that these events affect vulnerable FIs in a fashion similar to other systemic risks. Natural disasters are spatially correlated events that affect many households and firms concurrently, leading to large loan losses. Thus, these events destroy the capital of FIs, and because of minimum capital requirements, lead to a credit contraction in the period following a severe event, slowing recovery for affected communities.

We illustrate these dynamics for an FI in Peru that specializes in microfinance and is vulnerable to severe El Niño events. El Niño creates catastrophic flooding in northern Peru (McPhaden, 2002). During the severe events of 1983 and 1998, rainfall was roughly 40 times normal levels for the months January to May (Skees and Murphy, 2009). This extreme weather leads to deaths and permanent injuries; destroys roads, bridges, homes, and businesses; inundates crops; and increases food prices, water-borne illnesses, and pests. Roughly 20% of the portfolio of this FI is in the vulnerable region. We participated in several development projects in Peru and collected data in collaboration with this FI during that field work.¹

¹These projects were conducted by GlobalAgRisk, Inc. and were funded by USAID, the Bill & Melinda Gates Foundation, the United Nations Development Programme, and GIZ, a German development agency.

Insurance and disaster recovery

von Peter et al. (2012) also find that transferring risk to insurance markets may reduce the consequences of natural disasters. Their results suggest that it is only the uninsured portion of the loss that creates negative economic consequences. For well-insured events, the economic effect is neutral or even positive. These macroeconomic results motivate an examination of the underlying microeconomic mechanisms contributing to the value of insurance. We propose that this effect is partially explained by insurance reducing disruptions in the banking sector and so increasing the supply of credit after an event. Insured borrowers may be less likely to default after a severe event. By reducing loan losses, insurance preserves the capital of FIs. This capital can then be directed toward lending for reconstruction. We add insurance to the banking model in this paper and demonstrate that it protects lender capital and increases the supply of credit after the event.

In recent years, the development community has invested in a variety of projects to cultivate insurance markets in developing and emerging economies, including those to address natural disaster risk. These projects have tended to focus on insurance for households, especially the poor. While a variety of fascinating case studies have emerged, so have many challenges including limited demand and high transaction costs that threaten the viability of these markets (Murphy et al., 2011; Skees, 2008).

We took a different approach in Peru by using donor support to develop insurance products for FIs and other firms. For FIs, insuring against severe El Niño does not reduce the loan losses of its borrowers, but it offsets the resulting capital losses with an insurance payout. Thus, while the use of insurance by FIs would not directly address the disaster-related hardships of borrowing households and firms, it may prevent credit contractions that exacerbate disaster losses.

Some research also suggests that for managing disaster-related credit risk, insurance for FIs may be more effective than that for households. For example, Miranda and Gonzalez-Vega (2011) model a representative, dynamically optimizing microfinance borrower also using the case of a Peruvian microfinance market vulnerable to El Niño. Their results indicate that insurance purchased by individual borrowers is likely to increase credit risk by reducing their capacity to manage idiosyncratic risks. Evaluating the potential of subsidized insurance for individual borrowers, they note that the subsidies must be so large to improve borrower repayment that the cost likely outweighs the benefit. Finally, Miranda

and Gonzalez-Vega examine a scenario in which the FI insures against its disaster exposure. Insurance slightly reduces the expected value but greatly reduces the volatility of the equity of the FI over the evaluation period.

After modeling the consequences of El Niño risk for the Peruvian microfinance intermediary, we evaluate the effects of El Niño insurance — whether the modeled lender chooses to insure and how insurance affects its performance. Unlike Miranda and Gonzalez-Vega (2011) who examine the case of a fully capitalized FI (i.e., one with a capital ratio of 100%), we consider a lender operating in the vicinity of its minimum capital requirement to evaluate the effects of capital constraints on the supply of credit in this risky environment.

2.1.2. Model

A representative lender operating in a competitive market attempts to maximize current and discounted future dividend payments to shareholders over an infinite horizon. This lender manages a stock of equity k , held by international investors, and is unable to attract additional equity investments. Lender income comprises three elements: revenues, expenses, and adjustments in asset values. Each period, the lender generates revenue by making loans l at interest rate r . Lending is exposed to the production risks of borrowers, leading to an exogenous, random nonrepayment rate $\tilde{\xi} \in [0, 1]$. Nonrepayment occurs due to idiosyncratic shocks as well as the realization of a natural disaster to which production is vulnerable. The lender borrows from international markets at rate r^d and incurs origination costs associated with finding and evaluating borrowers. Because of the limited supply of good borrowers, this cost increases as the market grows, taking the form αl^2 . Finally, the lender adjusts its value based on loan losses $\tilde{\xi}l$. Thus, its income function is

$$\pi = r(1 - \tilde{\xi})l - r^d(l - k) - \alpha l^2 - \tilde{\xi}l. \quad (2.1)$$

The regulating supervisor and equity and liability holders monitor the lender by its capital ratio c , which takes the form

$$c = \frac{k + \pi}{(1 - \tilde{\xi})l}. \quad (2.2)$$

The lender is motivated to keep the ratio at a target level \bar{c} . If the lender's capital ratio falls below this target, the regulating supervisor intervenes, restricting operations and implicitly

sending a signal to liability holders of the lender's risk. If the lender operates above the target, equity holders lose confidence in the lender and begin divesting. Thus, deviations from the target lead to the penalty $g(k, l) \equiv \beta(\bar{c} - c)^2 l$ such that deviations are punished at an increasing rate.

Lender income, penalties, and dividend payments affect lender equity, leading to the equity evolution equation

$$k' = (1 - \nu)k + \pi - g \quad (2.3)$$

where ν is the dividend rate. Given these conditions, we formulate the lender's problem with the Bellman equation

$$V(k) = \max_{l \geq 0} \nu k + \delta E_{\bar{\xi}}[V(k')] \quad (2.4)$$

where δ is the lender's discount rate.

Deterministic steady state

The model structure prevents describing its mechanics analytically; therefore, we solve the deterministic version of this model to demonstrate the lender's behavior. Let $\bar{\xi} \equiv E[\tilde{\xi}]$. The Euler conditions are

$$V_l : \delta k'_l V_{k'} \leq \mu \quad (2.5)$$

$$l \geq 0, \mu \leq 0, l > 0 \implies \mu = 0 \quad (2.6)$$

$$V_k : \nu + \delta k'_k V_{k'} = V_k. \quad (2.7)$$

Assuming an interior solution, (2.5) leads to the result that the lender originates loans until marginal revenue equals marginal cost

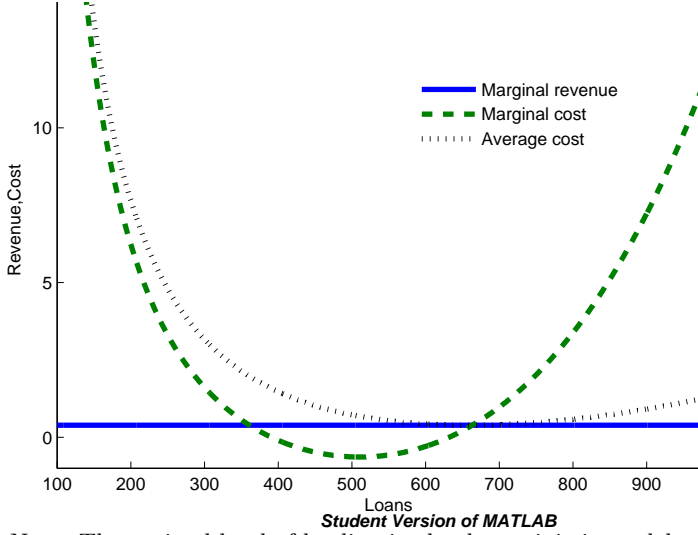
$$r(1 - \bar{\xi}) = r^d + 2\alpha l + \bar{\xi} + g_l. \quad (2.8)$$

This inverse supply function can be solved for l , leading to an optimal policy function $l^*(k)$. The supply of loans is increasing in the interest rate r and decreasing in loan losses $\bar{\xi}$, borrowing costs r^d , and origination costs α . At the steady state, economic profits equal zero so that

$$r(1 - \bar{\xi}) = \left[r^d + (\nu - r^d) \frac{k}{l} \right] + \bar{\xi} + [\alpha l + \beta(\bar{c} - c)^2]. \quad (2.9)$$

Thus, the model adheres to the result from production theory that competitive markets lead marginal revenue to equal marginal cost and average cost. This result is shown in Figure 2.1 based on the model calibration described in the next section. Equation (2.9) also demonstrates that interest rates comprise three elements: 1) average financing costs for the lender, 2) loan losses, and 3) operational costs.

Figure 2.1: Deterministic solution



Note: The optimal level of lending in the deterministic model equates the marginal revenue, marginal cost, and average cost of lending.

Model with insurance

We additionally consider a case in which the lender can use an insurance-like mechanism to transfer its disaster risk. This insurance provides a payment based on an occurrence of the disaster, which is measured by indicator t . The lender can buy a sum insured $q \geq 0$ at premium rate p and receive a payout based on the function $i(t)$. Thus, the insurance protects against the disaster event but does not directly reduce the loan losses of the lender. The lender's new income function is

$$\pi = r(1 - \tilde{\xi})l - r^d(l - k) - \alpha l^2 - pq - \tilde{\xi}l + qi(t). \quad (2.10)$$

2.2. Methods

This section describes model calibration and the numerical solution techniques used to solve the model. Mapping disaster severity to economic exposure is a non-trivial task. For example, Strobl (2012) models GDP losses from hurricanes using data on population data and the

Table 2.1: Calibration summary

Parameter	Symbol	Value
Lending interest rate	r	41.9%
Borrowing interest rate	r^d	5.5%
Origination expense	α	0.0004
Capital penalty	β	25
Discount rate	δ	0.94
Dividend rate	ν	6.4%
Loan loss rate	$\tilde{\xi}$	{6.6%, 10.1%}
Capital requirement	\bar{c}	14%
Insurance payout	i	{0,1}
Insurance trigger	\bar{t}	24.5°
Insurance premium	p	8.05%
Disaster probability	$P[t \geq 24.5^\circ]$	4.6%

Note: Brackets indicate values under non-disaster and disaster conditions, respectively.

wind speeds and paths of hurricanes. El Niño-related loan loss data from Peru are available for a single severe event and at the portfolio level, limiting opportunities to observe portfolio losses across events of different severities. Moreover, because the last severe event occurred more than 15 years prior to the current risk assessment, the capacity of historical losses to predict current exposure is greatly reduced. Given the paucity of data, we elicit the expert judgement of risk managers in the representative lender, using historical loss data as one reference point, to estimate the current exposure of this intermediary. Additionally, using current primitive financial parameters for the representative lender such as its lending and borrowing interest rates and origination expenses, we evaluate the financial and operational consequences of the estimated disaster-related loan losses. Table 2.1 summarizes calibration values.

2.2.1. Financial intermediary calibration

The representative lender is calibrated for one of several FIs with whom the authors collaborated in risk assessment and stress-test modeling. This FI specializes in microfinance with an average loan size of USD 1600. Its stated mission is to provide financial services to micro and small enterprises with the hope of improving quality of life for lower income people.

Data from the monthly income statement and balance sheet of the FI are available from the Peruvian banking regulator’s website.² We calibrate financial performance parameters

²www.sbs.gob.pe

such as the effective annual lending interest rate (41.9%), borrowing interest rate (5.5%), and dividend rate (6.4%) using the average values from July 2009 to June 2012. During the evaluation period, the regulating supervisor required this type of FI to maintain a capital ratio of at least 14%, which we treat as the target capital ratio \bar{c} .

Origination expenses α result from a combination of administrative expenses, including investments in human resources, management information systems, research and development for new financial products, and geographic expansion. Identifying these expenses in the historic data is not possible; however, model stationary is a result of the convexity of origination expenses. We assume that the lender is operating in the vicinity of the mean of its steady state distribution of equity. Thus, by examining the level of equity held by the FI, we can infer the approximate origination expenses that lead to this outcome. We scale the model by a factor of one over one million so that equity is roughly USD 80 (instead of USD 80 million), leading to an α of 0.0004.

The parameter β on the capital penalty requires some logical constructs to calibrate. Deviating from the capital requirement may have direct financial implications (e.g., higher borrowing costs) and indirect ones (e.g., the supervisor dismissing board members). Both direct and indirect implications contribute to the value of β for the representative lender, making it difficult to measure. We consider a desirable penalty calibration one in which the risk of the penalty affects lender behavior (e.g., holding capital in excess of the minimum requirement), yet the penalty is not so stringent that it leads the modeled lender to insolvency when shocks occur. A calibration of $\beta = 25$ meets these conditions. Finally, following Mendoza and Quadrini (2010), we set the discount rate δ at 0.94.

2.2.2. Risk survey and expected losses

The FI surveyed its office and credit risk managers regarding their perceived vulnerability of outstanding loans to severe El Niño. Twenty seven participants completed the survey from four vulnerable regions: Piura, Lambayeque, La Libertad, and Ancash. The survey included an open-ended question asking participants whether they are concerned about the risk of a severe El Niño. The expert responses offer a nuanced perspective on the diverse credit risks associated with these events:

- “If a similar event occurs as that in 1998, we would certainly have negative consequences for the entire economy, especially because the area we serve depends heavily

on the viability of roads. These roads being blocked or interrupted by landslides would affect significantly the normal operations of our commerce and transport clients.”

- “We are concerned by severe El Niño. Our agency is in the Piura office and the city-level infrastructure is unable to prevent flooding because the main channel of the river runs through the city. Also, we have loans in grape production and other export products which are the main source of income for the rural area around the city, including an important source of income for dependent laborers. At the office in Unión, the river floods the farmland, as it has no proper outlet, and the rain affects agricultural products such as cotton, corn, and rice that provide the main income in the area.”
- “As the waters warm from El Niño, the aquatic species and fishing industry will move away from our coastline, leading to a shortage of fish.”
- “El Niño brings torrential rains that would cause serious harm to people, especially to the thousands of low income families living in mat huts.”

The survey respondents reported agriculture, commerce (i.e., firms in retail), transportation, and fishing as the most vulnerable sectors. Table 2.2 provides the average expected loan losses for each sector and region. Combining these estimates with its portfolio allocations indicates that the FI expects to lose 15% of the value of its loan portfolio in the vulnerable regions if a severe El Niño occurs. This type of FI anticipates to recoup about 60% of loan losses through exercising rights to collateral, implying that the expected default rate in the region for this event is 25%. Aggregating these results to the total portfolio, across all regions, the FI expects to lose 3.5% of the value of its outstanding loans from a severe El Niño event. This estimate is consistent with historical performance during the last severe El Niño of 1997–1998 and risk assessment results for other FIs in the region (Collier, 2010; Collier et al., 2011; Collier and Skees, 2012).

Table 2.2: Expected loan losses (%)

	Piura	Lambayeque	La Libertad	Ancash
Agriculture	38	21	32	30
Commerce	26	10	15	33
Transport	18	3	22	16
Fishing	24			15

2.2.3. Probability of severe El Niño

Severe El Niño events are the result of a disruption in ocean and atmospheric circulation along the equatorial Pacific. This disruption increases the Pacific surface temperature, creating convection. As this warm, moist air moves west, it meets the cool air descending from the Andes in the east. The result is an extended period of torrential rainfall and flooding in northern Peru and southern Ecuador (Lagos et al., 2008). Because of this physical process, Pacific ocean temperatures are the key measure of El Niño used by climate scientists (e.g., see Wolter and Timlin, 1998) and the method we use to estimate the probability of El Niño.

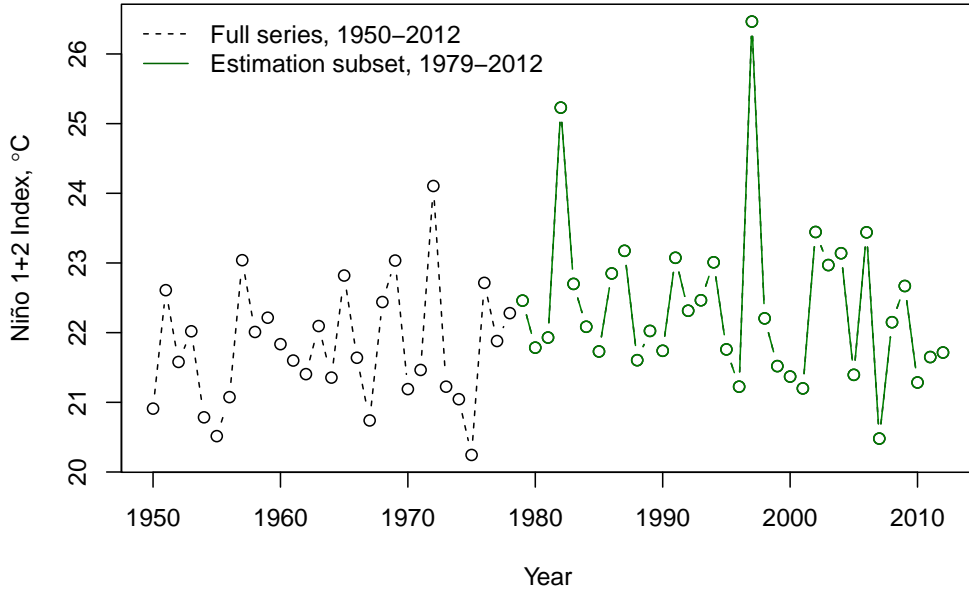
Niño 1+2 is a measure of ocean temperatures near the coast of Peru and Ecuador collected by the National Oceanic and Atmospheric Administration (NOAA) of the United States. Khalil et al. (2007) find that rainfall in northern Peru is highly related to Niño 1+2. Ocean temperatures in this region follow an annual cycle. If El Niño emerges, flooding in northern Peru generally begins in February. Elevated ocean temperatures predate extreme rains. Our analyses suggest that average reported temperatures for Niño 1+2 for November and December are a strong predictor of impending torrential rains in northern Peru and so serve as the index by which we measure El Niño severity.

NOAA measures Niño 1+2 using a combination of data from ocean buoys, satellite sensors, and transocean liners. Data are available from 1950³; however, the amount of buoys increased significantly in the 1970s and satellite readings were not available until the early 1980s. As a result, we use data from 1979 to 2012. Figure 2.2 shows the full time series and the data subset used in our probability estimations. Long-term historic data show multi-decade cycles in El Niño events; and significant debate exists in the scientific community on the effects of anthropogenic climate change on El Niño (Collins, 2005; McPhaden, 2002; Merryfield, 2006; van Oldenborgh et al., 2005; Yeh et al., 2009). Regarding our Niño 1+2 Index, no time trend is present in either series, and the augmented Dickey-Fuller test reports that neither the full time series (aDF=-4.19, $p < 0.01$) nor the estimation subset (aDF=-4.21, $p = 0.01$) has a unit root, an indication of stationarity.

Two severe El Niño events occur in the data series, in years 1982 and 1997. These elevated ocean temperatures in November and December correspond with flooding in northern Peru several months later, beginning in approximately February of 1983 and January of 1998, respectively. Both severe events caused significant damage, leading to many problems

³<http://www.cpc.ncep.noaa.gov/data/indices/ersst3b.nino.mth.81-10.ascii>

Figure 2.2: Niño 1+2 Index



Note: The Niño 1+2 Index is generated from the average Pacific surface temperatures in the region Niño 1+2 during November and December each year. Elevated temperatures such as those in 1982 and 1997 are associated with an impending severe El Niño. We use a subset of the total time series for which data quality is higher.

in the financial sector. Because the economy and financial system have changed so significantly since their occurrence, comparisons of the consequences of these two severe events are difficult. As a result, we treat severe El Niño as a binary outcome. Based on discussions with climate scientists and reports on what ocean temperatures lead to significant losses in Peru, we define a temperature t exceeding 24.5° on the Niño 1+2 Index as a severe El Niño event.

We assess the probability of severe El Niño using maximum likelihood estimation (MLE) of the generalized extreme value (GEV) distribution. This distribution is commonly used for estimating infrequent events with limited data due to its flexibility as its parameters allow it to approximate a variety of long-tailed distributions. It is derived from an assumption of the data's asymptotic convergence, namely it is the limiting distribution of the maxima of N independently and identically distributed, random variables drawn from a distribution as $N \rightarrow \infty$ (Cameron and Trivedi, 2005). The cumulative distribution function for the GEV distribution is

$$G(x; \mu, \sigma, \kappa) = \exp \left\{ - \left[1 + \frac{\kappa(x - \mu)}{\sigma} \right]^{-1/\kappa} \right\} \quad (2.11)$$

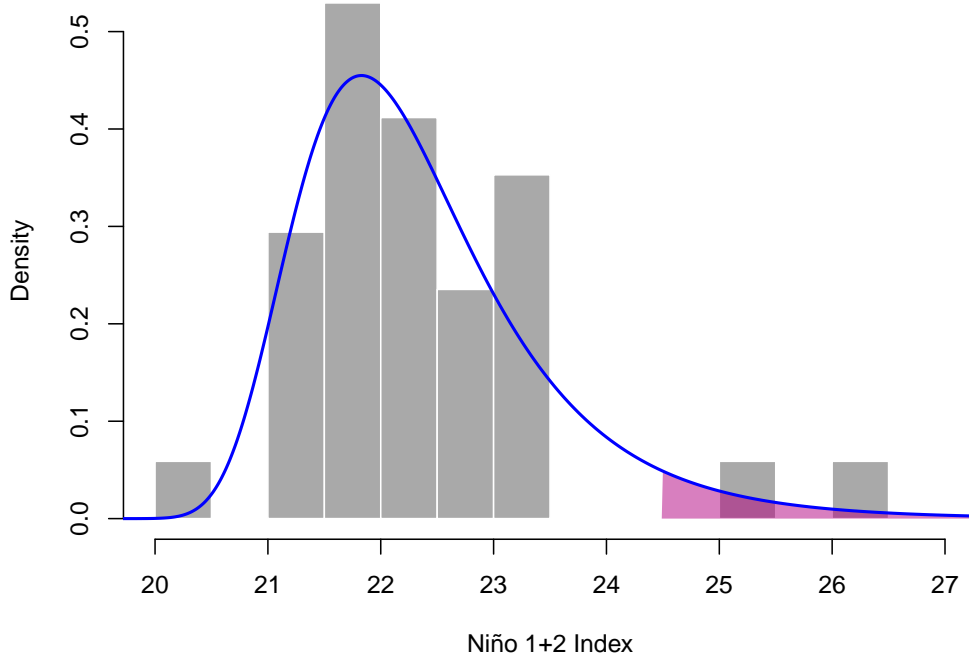
where μ , σ , and κ parameterize the location, scale, and shape of the distribution, respec-

tively (Jenkinson, 1955). The GEV distribution has three types, which depend on the value of κ . Type 1, the Gumbel distribution, occurs when $\kappa = 0$ and is the most familiar for many economists as the logit model is derived from it (Cameron and Trivedi, 2005). Its tail decreases exponentially, similar to the normal distribution. Type II, the Fréchet distribution, occurs when $\kappa > 0$ and is similar to Student's t , Pareto, and Cauchy distributions whose tails decrease more gradually. Type III, the reverse Weibull distribution, occurs when $\kappa < 0$ and is marked by relatively short tails, similar to the beta distribution (Woo, 1999).

Smith (1985) demonstrates that the GEV distribution can be estimated using MLE, showing that the typical asymptotic properties of MLE estimators hold if $\kappa \geq -0.5$. The results of our MLE using the Niño 1+2 index for years 1979 to 2012 provide GEV distribution parameters of $\mu = 21.861$, $\sigma = 0.809$, and $\kappa = 0.041$, indicating that Fréchet is the best fitting distribution for this index. Figure 2.3 provides a histogram of the index values and the estimated probability density function. Based on this analysis, the annual probability of severe El Niño is

$$P[t \geq 24.5^\circ] = 1 - G(24.5^\circ) = 4.6\%. \quad (2.12)$$

Figure 2.3: Histogram and GEV distribution



Note: The histogram and MLE estimation of the generalized extreme value distribution for the Niño 1+2 Index are shown. The shaded area under the curve identifies the probability of a severe El Niño, which we estimate as 4.6% annually.

2.2.4. El Niño insurance

A parametric insurance product is now sold in Peru to address the adverse consequences of event-related flooding. That contract uses the Niño 1+2 Index as the sole basis of payments. Because the Niño 1+2 Index measurements predate Niño -related flooding in northern Peru, El Niño insurance has the potential to make payments before disaster losses emerge. Thus, it is likely the first regulated forecast insurance in the world (Collier and Skees, 2012).

Following our treatment of El Niño as a binary event, we use a simplified insurance contract structure in this paper such that the full sum insured is paid if severe El Niño occurs

$$i(t) = \begin{cases} 1 & \text{if } t \geq 24.5^\circ \\ 0 & \text{o.w.} \end{cases} \quad (2.13)$$

From discussions with insurers and reinsurers, we estimate that for this risk the loads for commissions, administration costs, etc., would be approximately 75% of the actuarially fair rate, resulting in an annual premium rate of about 8.05% of the sum insured for this stylized contract.⁴

2.2.5. Solution techniques

The Bellman equation (2.4) is solved using the method of collocation (Judd, 1998; Miranda and Fackler, 2002). The collocation method calls for the value function $V(k)$ to be approximated using a linear combination of n known basis functions ϕ_j :

$$V(k) \approx \sum_{j=1}^n z_j \phi_j(k). \quad (2.14)$$

The unknown coefficients z_j are then fixed by requiring the value function approximants to satisfy the Bellman equation (2.4), not at all equity levels k , but rather at n judiciously chosen collocation nodes k_j . The collocation method replaces the Bellman functional equations with a set of n nonlinear equations with n unknowns that are solved using Newton's method. The collocation method can generate highly accurate approximate solutions to the Bellman equation, provided the basis functions and collocation nodes are chosen judi-

⁴We would like to thank Grant Cavanaugh for his contributions to estimating the probability of El Niño. For an in-depth analysis on this topic, please see Cavanaugh (2013). Additionally, insurers in Peru offer a linearly increasing payout structure. For example, one contract has a trigger of 24° and exhaustion point at 27°, where the full sum insured is paid. As a result, the probability estimates developed here do not apply to those contracts.

ciously and their number n is set adequately high. We chose Chebychev polynomials and equally-spaced nodes to compute the approximate solutions for the Bellman equations. The solution was computed using the CompEcon 2012 Toolbox routine *dpsolve* (Miranda and Fackler, 2002).

2.3. Results

This section describes the optimal behavior of the lender and simulates the effects of a natural disaster on its operations. We also compare results in which the lender retains its disaster risk with those in which the lender transfers it using insurance.

2.3.1. Lender simulation, retaining risk

Figure 2.4 illustrates results for the model in which the lender retains its risk, the model without insurance. In the figure, each period represents a year, and the disaster occurs in Period 0. The figure shows that because of risk, the lender sets loan allocations so that it operates with a buffer above minimum capital requirements. This result is consistent with the behavior of the FI, which during the evaluation period, maintained an average capital ratio of 16.8%.

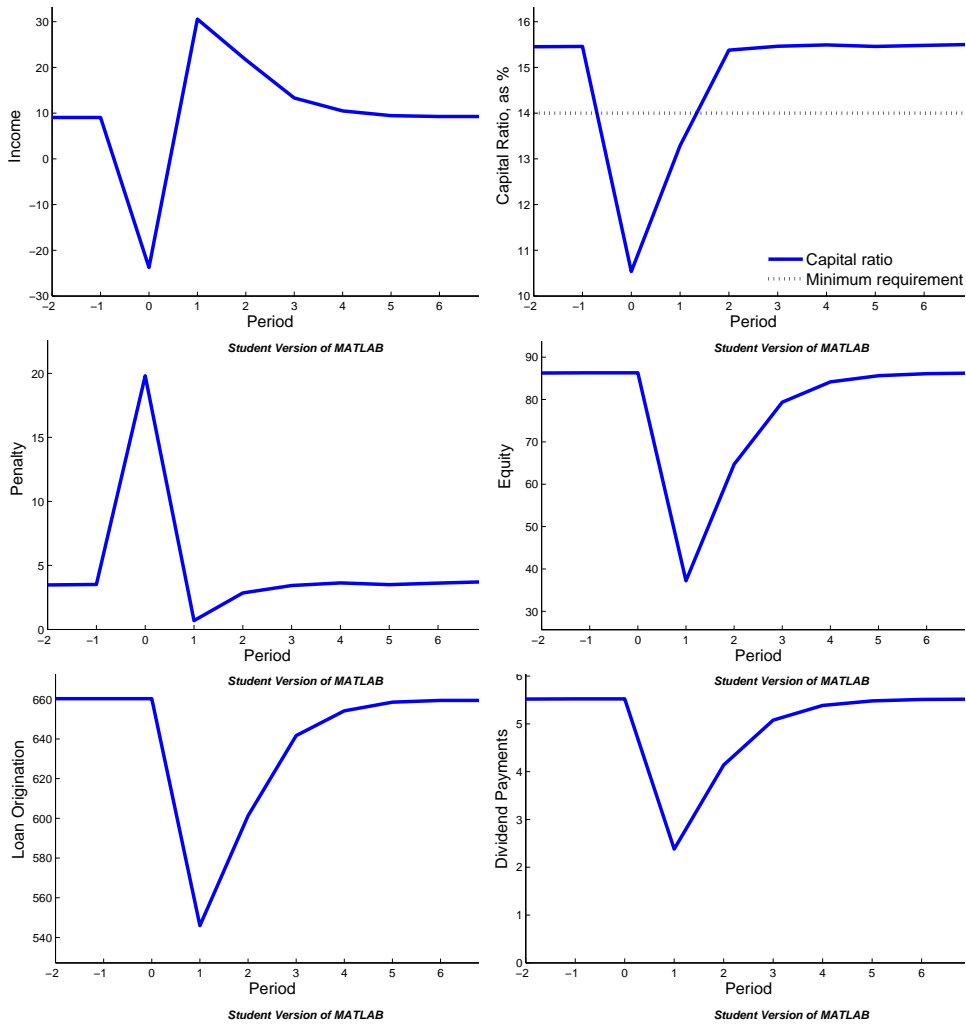
The disaster creates loan losses that lead to income losses. Income losses reduce the capital of the lender and push its capital ratio below the minimum requirements. Given this smaller equity base, the capital requirement motivates the lender to realign its balance sheet by originating fewer loans, disrupting the provision of credit in the market.

Recovery occurs as the lender retains earnings during the periods following the disaster. Facilitating this recovery is the ready supply of good borrowers created by the credit contraction, leading to lower origination expenses and so higher income. These results indicate that loan origination returns to pre-disaster levels after approximately four to five years, which is consistent with the expected recovery period communicated by credit risk managers in FIs in Peru.

2.3.2. Capital constraints and the 1998 El Niño

These results motivate the question: did the 1998 El Niño create the capital problems demonstrated in the simulation results? While the microfinance institution for which the model is calibrated was not operating during that event, we examine the performance of

Figure 2.4: Simulation, risk retained



Note: Simulation results demonstrate the financial and operational consequences of a severe El Niño event for the modeled lender.

other FIs in the region. Figure 2.5 shows the ratio of equity to loans, approximately the capital ratio, for three FIs operating in the region during 1998. Those FIs are owned by local municipalities and provide credit to households and firms of a variety of sizes.

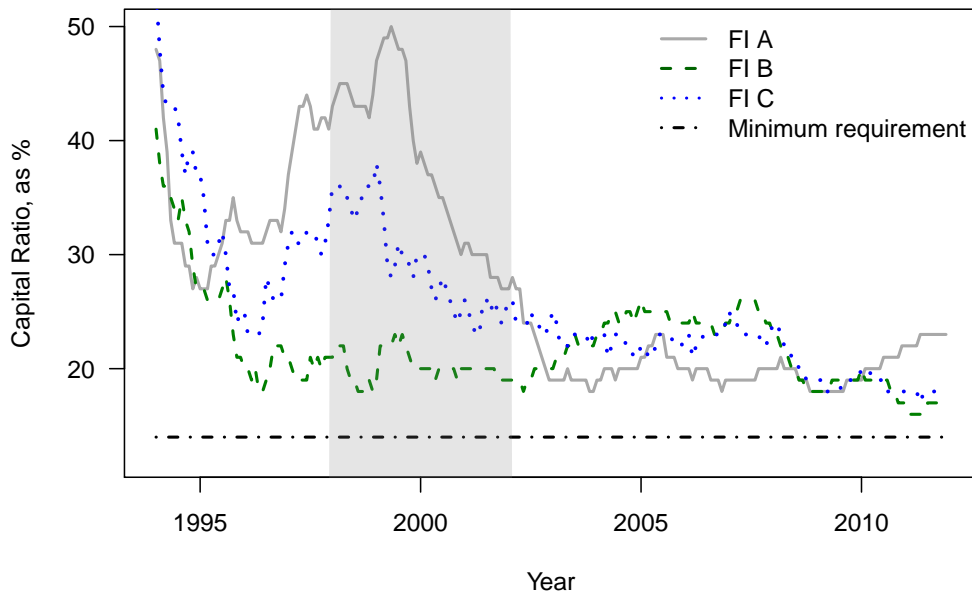
This time series illustrates a common pattern that FIs in newly developed credit markets often operate with large capital reserves but reduce these reserves as markets grow. Lenders in nascent markets are managing a great deal of risk, such as lending to borrowers with no previous credit history and developing and testing underwriting procedures. These lenders are also building a clientele large enough to meet its lending capacity. As markets mature, the capital ratios of FIs converge toward minimum requirements.

During this maturation process in northern Peru, El Niño occurred. The shaded area in Figure 2.5 is a four year period beginning with the approximate onset of the El Niño

event in January 1998 and ending in December 2001. The months during and after the El Niño event represent a period of high volatility in the capital ratios of each FI; however, the figure does not mimic the plummet and recovery of the capital ratio shown in Figure 2.4. Because these FIs were not operating near the minimum capital requirements, their operations were not constrained by capital losses. Instead, Collier and Skees (2012) report that these FIs used their excess capital to increase lending to improve their performance indicators following the disaster. For example, portfolio at risk (PAR) is an indicator describing the proportion of the portfolio on which loan payments are a certain number of days (e.g., 90) overdue. Assuming an FI can identify creditworthy borrowers, a dramatic increase in lending following a disaster would reduce PAR.

While the excess capital reserves held by these FIs in 1998 minimized the potential disruptions of El Niño on their operations, their reserves are now much closer to the minimum requirements. Thus, these FIs are no longer in a position to rely on a strategy of growing to recover from a severe event.

Figure 2.5: Financial intermediary capital ratios and the 1998 El Niño



Note: During the severe El Niño of 1998, financial intermediaries held large capital reserve; now they do not, increasing their vulnerability.

2.3.3. Lender simulation, transferring risk

Figure 2.6 illustrates results for the model in which the lender transfers its risk. The lender chooses to insure a portion of its disaster exposure. With this protection, the lender reduces the buffer it holds above minimum requirements, increasing its loan allocation. When the disaster occurs, the insurance payout offsets loan losses and so smooths lender income, protecting its equity and maintaining the stability of the capital ratio. This protection not only allows the lender to avoid the adverse consequences of operating below the capital requirement, but also stabilizes dividend payments to shareholders. Perhaps most importantly from a social perspective, the insurance prevents the contraction of credit during the period following the disaster.

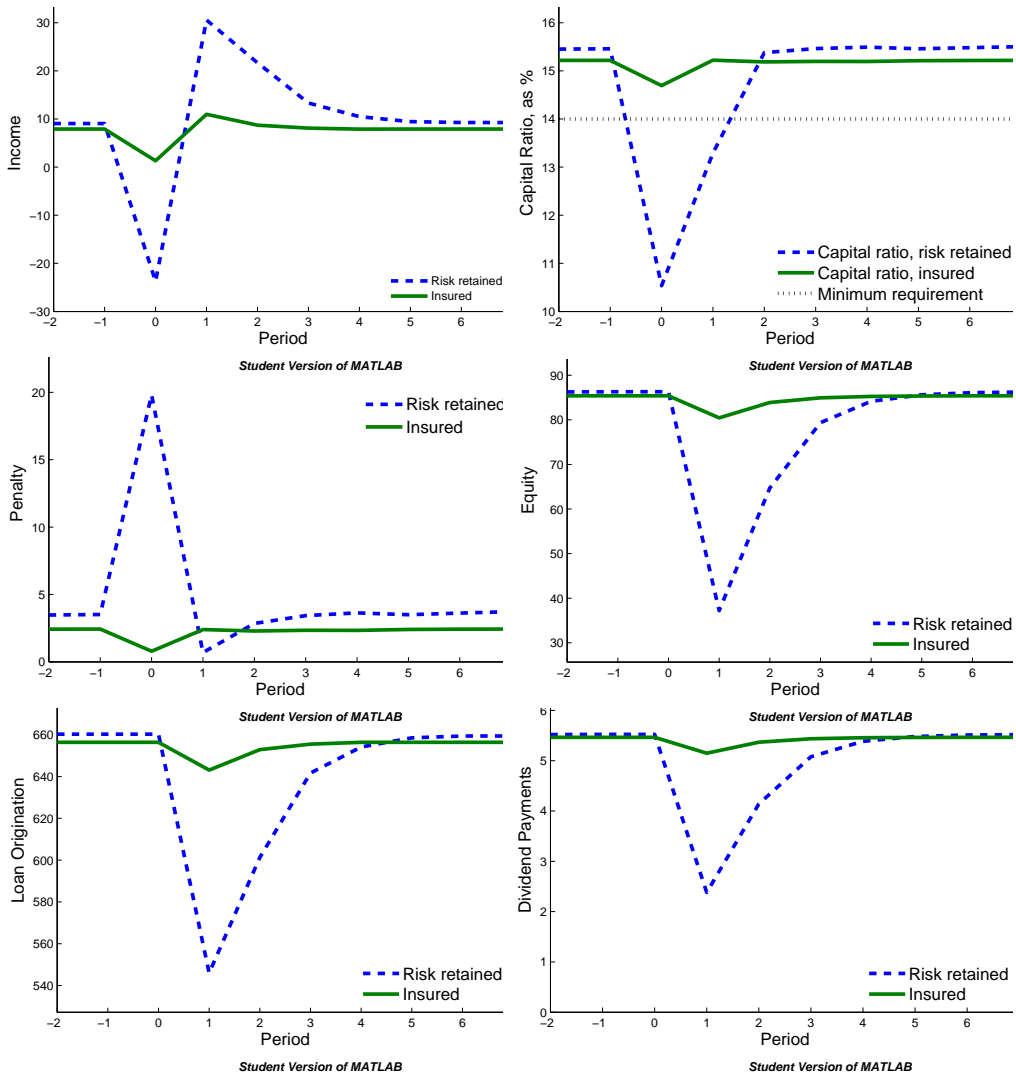
Examination of the optimal sum insured indicates that it is set at a point that smooths the capital penalty across disaster and non-disaster states of the world. Figure 2.7 illustrates that insurance is chosen to match the potential penalty that the lender would pay if the disaster occurred. Other common uses of insurance are income and asset protection. This figure also shows for each period the loan losses the lender would incur during a disaster and the normal (non-disaster) income the lender can expect, illustrating that income and asset risk are not driving insurance purchase. Instead, the lender is minimizing the cost of the event by managing its capital ratio to avoid falling below minimum capital requirements.

An important public policy question pertains to the effect of insuring on access to credit more generally — does the cost of insuring reduce the supply of credit in periods preceding the disaster? The insured lender is more leveraged than its uninsured counterpart (i.e., its capital ratio is lower in periods preceding the disaster), and the additional revenue generated from this leveraging at least partially offsets the cost of insuring. For this model's calibration, the difference in origination between the insured and uninsured lender in the period before the disaster is less than one percent, a difference within the margin of modeling error. Thus, we conclude that insuring does not reduce the supply of credit during non-disaster periods.

2.4. Discussion

This research demonstrates that natural disasters can be systemic risks that significantly challenge FIs in vulnerable regions. These risks are likely to be more severe in developing and emerging economies and therefore deserve special attention in those jurisdictions. Because

Figure 2.6: Simulation, insured

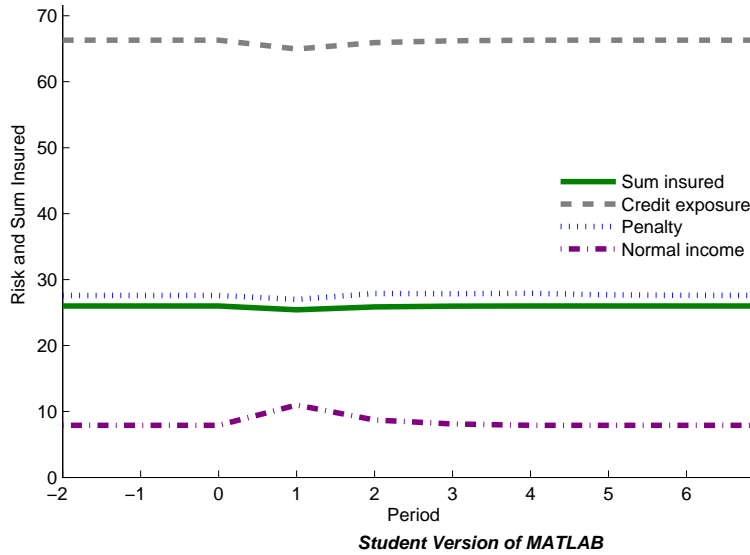


Note: Insurance reduces the financial and operational disruptions of severe El Niño.

FIs are instrumental to mobilizing investment after a disaster, increasing their resilience may substantially affect the development of vulnerable economies. A rich literature on managing systemic shocks in the financial sector exists, much of which can be applied to disaster risk.

Managing disaster risks is in the interest of FIs as these events disrupt income and dividend payments. Based on this research, a highly regarded FI in Peru that specializes in microfinance purchased El Niño insurance in 2011 and 2012. That FI reports that the insurance not only reduces its current vulnerability, but that it plans to use the insurance to increase financial inclusion in the vulnerable region. By reducing risk and stabilizing financial performance, insurance may also increase the willingness of investors to hold equity

Figure 2.7: Risk and sum insured



Note: The modeled lender insures to avoid regulatory penalties resulting from capital losses that would occur with an El Niño.

and other forms of capital in FIs operating in vulnerable regions.

Because of the many potential externalities in banking, systemic risk management relies heavily on public supervision and market discipline. Monitoring and encouraging FIs to proactively manage disaster risk is in the interest of supervisors, credit rating agencies, and investors in vulnerable regions. Regarding public interests, these events have the potential to disrupt the provision of credit, potentially exacerbating the consequences of natural disasters. While not explicitly modeled here, systemic events can also threaten the claims of depositors and other liability holders and lead to contagion in the financial sector. International standards require tailoring to allow for risk-based supervision of disaster exposures. Credit rating agencies and some investors employ rating methodologies that face many of the same limitations as international banking standards, emphasizing risks to large banks in developed economies, and so also require tailoring (Collier and Skees, 2012).

This research suggests that along with improving monitoring of disaster risks, encouraging risk management through mechanisms such as insurance provides both public and private benefits. For example, tailoring standards so that FIs could manage disaster risk concentrations using additional capital reserves, purchasing financial risk-transfer, and/or investing in diversification would allow FIs to minimize the cost of managing this risk. These cost savings would eventually translate to lower interest rates for borrowing households and firms.

One limitation of this research is that this model evaluates disaster risk in isolation of other systemic risks such as business cycles, currency fluctuations, commodity price shocks, etc. The variety of risks facing FIs motivate comprehensive risk management strategies that include layering financial mechanisms. Capital reserves are ubiquitous, flexible, important mechanism for managing small systemic shocks. For the risks of greatest existential concern to the FI, insurance represents an attractive alternative. Thus, the results of this research are most relevant for FIs worried about a specific natural disaster risk; for FIs exposed to many large systemic risks, its results overstate the benefits of insuring.

A second limitation is specific to index insurance, the risk transfer mechanism modeled here. While the core results of this research are generalizable to many types of insurance, index insurance tends to be more vulnerable to basis risk than is traditional insurance. Basis risk describes the possibility of a discrepancy between the severity of the disaster as experienced by the FI and that as measured by the index used for payouts. Basis risk is not explicitly modeled in this research. A risk management strategy that uses a combination of risk transfer, reserves, and other mechanisms is well suited to manage basis risk as capital reserves can be used to address the basis. Because index insurance substantially reduces moral hazard and adverse selection and so can be provided at a lower cost, it may be a more attractive mechanism to FIs than traditional insurance despite basis risk.

These findings offer many potential extensions through future research. Of primary interest is empirical research testing the modeled results. That research requires data on FIs operating in the vicinity of their minimum capital requirements that experience a natural disaster. Another important extension would be evaluating the consequences of disaster risk on foreign direct investment in vulnerable sectors, such as agriculture, and testing the potential of insurance mechanisms to add value in this context.

Chapter 3. Household Production, Disasters, Credit and Insurance

3.1. Introduction

This paper considers the implications for household economic growth of managing disaster-related credit risk via insurance designed for households versus financial intermediaries (FIs). Specifically, we evaluate the potential of these two approaches for lowering interest rates and increasing household investment in production. Central to the operations of FIs is assisting borrowers in managing credit risks through loan restructuring and forgiveness. Insurance for FIs enhances their ability to assist borrowers in managing cash-flow fluctuations and is compared with an approach in which households manage credit risks themselves by insuring.

While household vulnerability to disasters extends significantly beyond their credit liabilities, substantial development-oriented investment is being made in disaster insurance to cover household production loans, hoping to increase access to credit. Rather than addressing the broader issue of household vulnerability, this paper responds to these development projects, considering how best to manage household credit risk due to extreme events.

We evaluate managing this credit risk using index insurance, a mechanism which bases payments on an objective measure of a disaster (e.g., weather station data to estimate drought) and so can be used in a variety of contexts where traditional insurance is infeasible. Using a new panel collected in 2009, we study a smallholder population in northern Peru for whom the detrimental effects of risk-related credit constraints on productivity have been documented using previous panels (e.g., Boucher et al., 2008; Fletschner et al., 2010; Guirkingner and Boucher, 2008). Insurance against severe El Niño events is now offered in this region with the potential to be used to manage credit risk at the household or lender level.

Our results demonstrate two important benefits of designing index insurance to be purchased by lenders rather than borrowing households to manage disaster-related credit risk. First, designing products for lenders tends to lower at least some aspects of basis risk, the possibility of a discrepancy between the severity of the disaster as experienced by the

insured and that as measured by the index used for payouts. Second, it reduces the level of coverage needed to manage credit risk. Thus, insurance designed for lenders seems to offer effectiveness and efficiency gains over insuring at the household level that can translate into increased investment and economic growth in vulnerable economies.

3.1.1. Background and paper structure

Credit and insurance markets contribute to economic growth (Arena, 2008; King and Levine, 1993; Levine, 1997). Moreover, credit and insurance are complements, providing additional benefits when both markets are in place (Arena, 2008). For example, Grace and Rebello (1993) demonstrate that insurance facilitates borrowing by lowering the cost of capital for firms. Yet, credit can also act as a substitute for insurance (Binswanger and Rosenzweig, 1986); when insurance markets are underdeveloped, credit allows borrowers to transfer the risk of disagreeable states of nature to lenders.

These financial products allow households to reallocate funds across 1) time, and 2) states of nature. For example, credit allows households to leverage future wealth to expand current production opportunities. Still, both insurance and credit contain state-contingent and intertemporal aspects. Because of non-repayment risk, lenders must account for states of nature in setting interest rates. To prevent adverse selection opportunities, insurance must be sold in a period before the presence of a disaster can be predicted. As a result, credit and insurance products can be designed in ways where their functions significantly overlap. This substitutability allows for flexibility in product development.

Index insurance against natural disasters is expanding insurance markets in developing and emerging economies. It has gained some prominence as a mechanism to enhance credit markets and so increase financial inclusion. Among other examples, the World Bank has tested bundling index insurance against drought with agricultural production loans in Malawi (Global Facility for Disaster Reduction and Recovery, GFDRR, 2011). Insurance against severe El Niño is now being used by a microfinance intermediary (MFI) to protect its portfolio as it expands lending in northern Peru (Collier and Skees, 2012). Fonkoze, an MFI in Haiti, bundles household-level index insurance against earthquakes and severe storms with its loans (Fonkoze, 2011).

Insurance for households predominate development-oriented index insurance projects, yet many institutional constraints and high costs challenge the creation of insurance markets for households. The costs include household-level capacity building and delivery of

small-value insurance products. Household insurance against disasters will not follow the path of microcredit due to their myriad differences (Murphy et al., 2011). For example, with insurance it is the household that incurs the upfront cost and bears the counterparty risk, whereas with microcredit it is the lender. With some exceptions, the scalability and sustainability of household-level index insurance projects are unclear; many markets will not survive when donor support ends. Moreover, too much emphasis has been placed on index insurance as a developing country proxy for developed country agricultural insurance with insufficient consideration of its best use for contributing to economic development. That model focuses on protecting insureds from yield risk associated with a single crop in a single season. While this approach is widespread, it seems to fit poorly the needs of smallholders in developing and emerging economies and has likely limited the relevance of index insurance for managing disaster risks, leading to serious questions regarding its value for development (e.g., see Binswanger-Mkhize, 2012). These observations motivate renewed consideration of how insurance against disasters can be structured to facilitate economic growth and under what conditions viable markets are likely to emerge.

Markets established with products designed for financial intermediaries (FIs, e.g., banks, MFIs) are more likely to be viable because they lead to large-value sales with much lower transaction costs than household products. Moreover, FIs are quite vulnerable to disaster risk and so constrain lending to vulnerable regions and economic sectors (e.g., agriculture). Index insurance for FIs improves their ability to manage disaster risks and can enhance financial inclusion and lower interest rates (Collier and Skees, 2012; Miranda and Gonzalez-Vega, 2011). As a result, index insurance designed to manage the portfolio risks of FIs, rather than products for their borrowers, may be a more effective starting point for the development of disaster risk markets serving the financial sector (e.g., Skees et al., 2007). Given these institutional advantages, we consider the potential development implications for households of managing credit risk with insurance for FIs rather than households insuring themselves.

We develop a dynamic model in which households attempt to maximize current and future consumption through capital accumulation. Household production is exposed to a disaster risk, and a lender and insurer offer products to facilitate production. We begin modelling with a standard set of neoclassical assumptions — perfect, competitive, and complete markets, no transaction costs, etc. Under these assumptions, the net present value of any financial product is zero. The cost to lenders and insurers of managing the risks associated

with household production decisions are passed to households via borrowing interest rates and/or insurance premiums. State-contingent transfers occur at the actuarially fair rate, and intertemporal transfers occur at the representative discount rate. We design credit and insurance products to limit household risk in borrowing. Households strongly benefit from using credit and insurance in the model; however, under neoclassical assumptions lenders can manage disaster risk without the assistance of insurance markets. Introducing insurance provides no efficiency gains in managing credit risk.

Next, we alter several assumptions and examine the effects. First, we consider more limited access to market-rate funds for lenders so that short-term funds carry a higher interest rate. This yield curve increases the cost of managing disasters with credit for households; however, insurance can reduce this cost. We evaluate two financial structures: 1) the household purchases insurance and takes a traditional loan; and 2) the lender insures its portfolio and offers households a loan that includes disaster forgiveness. These structures generate identical cash flows for households. Insurance increases the efficiency of credit markets, and these gains are irrespective of who insures, households or lenders.

Second, we consider the implications of basis risk for index insurance products. Households and lenders require different disaster indices because household production is geographically concentrated compared to the portfolio of production investments held by the lender. We consider the case of a household using measurements from the nearest weather station as an index of the disaster while the lender uses a weighting of data from several weather stations that represent the geographic distribution of its portfolio. Using properties of estimators, we demonstrate that basis risk is lower for the lender product and illustrate the magnitude of the benefits of aggregation using a network of weather stations in Brazil. This result suggests that lender-level index insurance better addresses disaster-related credit risk than household-level index insurance.

Third and finally, we consider the condition of an imperfect relationship between the occurrence of a disaster and household losses. In this context, only a portion of households default when the disaster occurs; however, all insured households receive an index insurance payment based on the measure of the event. Each household is uncertain whether it will be one of the ones to default so, assuming a utility gain from insuring, a household-level index insurance market would motivate all households to insure. At the aggregate level, this strategy over-insures the credit exposure, which has the high opportunity cost of lowering household productive investments and so slowing economic growth. Alternatively, managing

disaster-related credit risk through lender-level index insurance in this context does not lead to over-insuring and so benefits households by lowering their borrowing costs, allowing them to increase productive investments.

To illustrate, we consider the case of a lender trying to identify *ex ante* which households would default in a disaster so as to only require these disaster prone households to insure. As an analogue to loan default, we evaluate the incidence of distressed land sales in northern Peru, selling productive land to cope with an adverse event. These data were collected in 2003, several years following a severe El Niño. Despite having detailed information on household demographics, their production, their location, etc., our ability to predict distressed sales is quite low.

3.1.2. Northern Peru and severe El Niño

Throughout, we use an illustrative case from northern Peru where severe El Niño events cause torrential rains and flooding. Along the Pacific coast, northern Peru is arid with good soils and irrigated agriculture, making it one of the most productive agricultural regions in Peru, employing 37% of the workforce, which almost exclusively works on small farms of less than 10 hectares (Instituto Nacional de Estadística e Informática, 2007; Trivelli, 2006). Moving from the coast eastward, the region is dominated by tree crops such as coffee and cocoa as the terrain changes quickly to semi-tropical small mountains. Farther east are the high Andes where agriculture supports local consumption. Fifty-four percent of the population in Piura, a region in the north, is at or below the poverty line (Instituto Nacional de Estadística e Informática, 2007). Organizations providing micro- and small-enterprise loans have grown significantly in recent years. For example, the loan portfolio of Caja Piura, one of the largest municipal banks in the region, grew from USD 3 million in January 1994 to USD 566 million in December 2012.¹ During the last severe El Niño, which occurred in 1998, rainfall in northern Peru was roughly forty times normal levels for the months January to April (Skees and Murphy, 2009). As a result, agricultural production declined by 30 percent (Cruzado Silveri, 1999). Extreme flooding damaged or destroyed roads, bridges, reservoirs, irrigation systems, and other public infrastructure, disrupting trade and creating additional losses for enterprises in the region. This diverse set of consequences translated into many loan repayment problems.

¹Data from the Peruvian banking supervisor, available at www.sbs.gob.pe

Data were collected on a panel of 720 farm households in this region. Households were surveyed in their homes by trained surveyors and asked, among other things, about their demographics, production, income, assets, financial service use, and risk preferences. Primarily, we rely on data collected in 2009, using it to estimate a farm-level production function and evaluate the effects of credit on production. The 2003 data that we use to model distressed land sales includes 1,071 households from the same panel.

3.2. Model

We develop a model in the tradition of neoclassical economic growth literature (e.g., Solow, 1956; Cass, 1965) and impose perfect market conditions. An infinitely-lived, risk-averse representative household attempts to maximize consumption by accumulating capital in the presence of natural disaster risk. A lender and insurer also enter the model, are risk neutral, and provide financial services to facilitate household production.

3.2.1. Households

A representative household attempts to maximize utility over an infinite time horizon, which is represented using the Bellman equation

$$V(k) = \max_{c, b \geq 0} U(c) + \delta E[V(k')] \quad (3.1)$$

where V is the household's value function, U its concave utility function, δ its discount rate, c consumption, b the amount it borrows from a local lender, and k household capital. Capital is comprised of consumable, illiquid, infinitely divisible assets. Each period households consume a portion of their capital $(1-s)$ and invest the remainder in production. Households invest their labor l inelastically. Households can borrow from a local lender to increase their potential returns. They pay an interest rate r , and fully collateralize the loan. Additionally, household production is vulnerable to a covariate disaster risk ψ . The household production function $f = f(sk, l, \psi)$ exhibits decreasing returns to scale.

Households operate under a cash flow constraint. If production returns are less than the loan payment ($f < (1+r)b$), then the borrower defaults and the lender exercises its right on collateral for the owed principal and interest, sells it at a fire-sale rate ν , and uses

that amount to settle the household liability.² For simplicity, we assume that borrowers only realize this liquidity problem when a natural disaster occurs, which happens with probability θ . Thus, borrowing households face the following income distribution

$$y = \begin{cases} f - rb, & \text{with probability } 1 - \theta \\ f_\psi - rl - \nu((1+r)b - f_\psi), & \text{with probability } \theta \end{cases} \quad (3.2)$$

where f_ψ represents returns under disaster conditions and $\nu > 1$. Households choose whether to consume net income or save it to contribute to next period's capital stock. Therefore, capital evolves based on the process

$$k' = y + (1 - \gamma)sk \quad (3.3)$$

where γ is the depreciation rate, $\gamma \in [0, 1]$.

3.2.2. Lender

The lender serving the representative household borrows all funds from an international bank at interest rate r and lends locally. With fully collateralized loans, the lender and international bank do not incur risk and so lend based on the intertemporal discount rate, $r = (1 - \delta)/\delta$, which for modeling purposes is the same for all agents. Borrowers limit the use of credit due to their risk exposure. Maximizing household utility with respect to borrowing indicates that, among other things, the optimal loan allocation is a function of the disaster exposure of the household and its capital level.

The lender is a type of investor in its borrowers because as the capital of the borrower grows, the lender can generate more revenues. Rather than requiring full collateral, the lender offers loan products that allow for delayed loan payments or principal forgiveness, effectively transferring a portion of the disaster risk of borrowers to the lender. Whether risk transfer is in the form of delayed loan payments or principal forgiveness, the expected cost of the transfer is passed to borrowers in the lending interest rate; the only sustainable strategy for relaxing collateral requirements is increasing interest rates. Given that this paper is intended to highlight the distinct and complementary functions of credit and insurance, instead of identifying optimal product structures through numerical solution techniques,

²Alternatively, we arrive at the same formulation if the household decides to sell its assets at fire-sale prices to meet its liabilities.

we describe frequently used product structures as archetypes, recognizing that households benefit from smoothing returns across agreeable and disagreeable states of nature, and make comparisons using the modeling framework.

Because the disaster occurs with probability θ , the actuarially fair cost of risk transfer for a product that provides a full payment in disaster periods is θ . Households pay for risk transfer during agreeable states and forego payments in disagreeable states (i.e., households do not pay risk transfer premiums during disaster periods). As a result, the payment rate structure $p \equiv \frac{\theta}{1-\theta}$ is used throughout.

First, we consider a loan with a feature that forgives loan interest for the first period and defers the payment of the loan one period. The expected cost to the lender of offering this interest rate forgiveness is θrb so the interest rate for the loan with a deferment clause is $r(1+p)$, which is paid the next period. Household cash flow associated with this loan is shown in Table 3.1. In the tables modeling cash flow throughout the paper, a potential disaster occurs after production allocations are made in the first period.

Table 3.1: Cash flow for loan with deferment clause

t	$t + 1$	$t + 2$	Condition
b	$-(1+r+pr)b$	0	Non-disaster
b	0	$-(1+r)b$	Disaster

Instead, the lender could offer a loan that had a disaster forgiveness clause, pending regulatory approval of such a product. In practice, the primary way that lenders offer debt forgiveness is loan write-offs after an adverse event. Lenders may continue to pursue an investing relationship with borrowers for whom they deemed default was unavoidable due to a disagreeable state of nature and may avoid exercising collateral to increase borrower productivity in the future. For this loan forgiveness clause, the actuarially fair interest rate would be $r+p(1+r)$. Household cash flow under this loan is shown in the perfect markets scenario of Table 3.2.

3.2.3. Insurer

Alternatively, a local insurer offers insurance against the natural disaster and transfers this risk to an international reinsurer. First, the insurance could also be used to defer the loan payment in a similar manner as the loan with a deferment clause described above. In this case, the sum insured is rb and the household takes out a traditional loan. The insurer accounts for the time value of money in establishing premiums and payouts, giving

Table 3.2: Household cash flow for loan with forgiveness clause

Scenario	Product Type	t	$t+1$	$t+2$	Condition	Comments
1. Perfect markets	Loan	b	$-(1+r+p(1+r))b$	0	Non-disaster	
		b	0	0	Disaster	
2. Increased short-term borrowing costs	Loan	b	$-(1+r+p(1+r_s))b$	0	Non-disaster	$r_s > r$
		b	0	0	Disaster	
3. Basis risk stress test	Loan and insurance	b	$-(1+r+p(1+r))b$	0	Non-disaster	Household or lender insurance
		b	0	0	Disaster	
		b	$-(1+r+p(1+r))b$	0	Non-disaster	
		b	0	0	Disaster	
4. Limited default	Loan and household insurance	b	$-(1+r+p(1+r))b$	0	Non-disaster	$-\epsilon_h^* < -\epsilon_h^*$
		b	0	$-\epsilon_h^*(1+r_s)(1+r)b$	Disaster	
		b	$-(1+r+p(1+r))b$	0	Non-disaster	
		b	0	$-\epsilon_l^*(1+r_s)(1+r)b$	Disaster	
4. Limited default	Loan and lender insurance	b	$-(1+r+p(1+r))b$	0	Non-disaster	$\omega \leq 1$
		b	0	0	Disaster	
4. Limited default	Loan and lender insurance	b	$-(1+r+\omega p(1+r))b$	0	Non-disaster	
		b	0	0	Disaster	

households the market interest rate for paying a premium one period before a potential payout would occur such that the total premium is $\frac{prb}{1+r}$. Households buy the insurance with a loan and repay the lender the next period. If the disaster occurs, the borrower uses the insurance payout to pay the interest on its loan, and takes out a loan of b to repay its current liability, deferring loan repayment to the third period at the market interest rate. This arrangement would lead to the same cash flow as shown in Table 3.1. Alternatively, the household could fully insure its loan for a premium of pb . This arrangement would lead to the same cash flow as shown in the perfect markets scenario in Table 3.2.

3.2.4. Summary

Under neoclassical assumptions, household cash flows for transferring risk using the loan and insurance products are identical. Both approaches transfer household capital from agreeable to disagreeable states of nature, an attractive quality for risk-averse households. By protecting households from default and liquidation, these mechanisms increase household expected utility and expected capital. In comparing credit and insurance, perhaps the most notable result is that under these assumptions, insurance adds no value in managing credit risk beyond the structures lenders can provide.

3.3. Household production and credit in northern Peru

This section describes household production and the effects of credit in northern Peru for the 2009 sample of farm households. Table 3.3 reports summary statistics. All monetary values are reported in Peruvian nuevos soles, which at the time of data collection was worth approximately USD 0.33. The most frequently planted crops for this sample are rice, organic bananas, mangos, limes, bananas, cotton, and corn. We fit a Cobb-Douglas production function for gross household agricultural income, see in Table 3.4, which shows the important contribution of land and fertilizer and pesticides to production.

Lenders in the region regularly restructure and write off loans. Often the first step is a “grace period” of about 90 days in which borrowers are not required to service a loan. In some cases, repayment flexibility is explicitly written into loan contracts such as loans in the fishing sector in Peru, which offer a year of deferred loan payment in the event of El Niño. As a precondition to offering loan restructuring and forgiveness, lenders must address problems of asymmetric information such as by monitoring borrowers or imposing incen-

Table 3.3: Summary statistics

	Median	Mean
Annual net farm income	6,877	11,440
Farm income (% of total)	62%	58%
Land (ha)	2.50	3.59
Household members	4	4.40
Education, head of household (years)	4.5	5.04
Home (monthly rental value)	100	124.7
Credit outstanding	2,000	5,329
% with land title		65
% with outstanding loan		54
Loans for agriculture (% of total)		85
Loans with collateral or co-signer (% of total)		34
Annual interest rate for microloan (%)		37

Note: The annual interest rate is the national average for microloans in the domestic currency, provided by the banking supervisor (www.sbs.gob.pe).

tive compatibility conditions that impute an additional cost on borrowers if they require loan forgiveness. For example, borrowers might face a “cooling off period” in which they could not borrow for a set amount of time after receiving loan forgiveness. For the 2009 sample in Peru, 34% of borrowers with formal credit posted collateral or used a guarantor. Additionally, agricultural lenders employ agronomists in field offices to monitor borrowers.

Boucher et al. (2008), Fletschner et al. (2010), and Guirking and Boucher (2008) used previously collected panels of this household data to study production in northern Peru and expand recognition of the sources of credit rationing. Before their work, research on credit constraints focused almost exclusively on supply-side rationing, lenders limiting the quantity of credit provided. They note that borrowers may also be unwilling to use credit if

Table 3.4: Agricultural production function

	Estimate	Std. Error	t value	Pr(> z)
(Intercept)	5.47	0.22	24.58	0.000
ln(land)	0.43	0.04	9.95	0.000
ln(labor)	0.14	0.04	3.40	0.001
ln(animals+machinery)	0.02	0.01	2.09	0.037
ln(fertilizer+pesticide)	0.33	0.03	12.24	0.000

F(4, 638): 134.7, p-value: 0.000

Adj. R squared: 0.45

Residual SE: 0.81

Outcome variable: ln(gross agricultural income)

Note: Land is measured in hectares, and labor includes hours worked by both paid labor and unpaid household farm labor. Animal and machine labor, fertilizer, and pesticides are measured in production costs.

the transaction costs of securing a loan are deemed too high or the risk of losing collateral too great.

Access to credit is likely related to household characteristics that also affect productivity such as wealth or skill, complicating direct comparisons across households. Research on credit and production often employs a switching regression model to address this endogeneity problem (e.g., see Carter, 1989; Feder et al., 1990; Guirkinger and Boucher, 2008). This approach first models a household’s propensity to be credit constrained then separates the sample into two populations, those who tend to be constrained and those who are not. Finally, production is modeled for each population, allowing for comparisons of the two groups. This approach answers well the question “how does production differ among those with and without a propensity to be credit constrained?” Still, it should be recognized that these populations may differ greatly. For example, consider a propensity model in which credit access is well-explained with a single variable, wealth. The switching regression will then compare production for the wealthy with the unwealthy.

Instead, we are interested in the question, “how would alleviating credit constraints, for example due to disaster risk, likely alter production for the average constrained household?” Rather than separating the sample to compare those with a high and low propensity to be constrained, answering this question requires comparing households with credit to those who are constrained but who have similar propensity scores (Rosenbaum and Rubin, 1983).

Surveyed households answered whether they currently have an outstanding loan, and if they did not, were asked whether they would accept a formal loan if offered one. Following Guirkinger and Boucher (2008), households that did not have a loan and would accept one are considered credit constrained. Propensity to be credit constrained is modeled with a logistic regression. We choose explanatory variables following (Carter, 1989; Carter and Olinto, 2003; Feder et al., 1990; Guirkinger and Boucher, 2008; Sial and Carter, 1996). These variables include

- Home: household reported rental value of its home in nuevos soles, a measure of wealth
- Education: years of educational attainment by the head of household (HoH), a measure associated with farmer skill (Lockheed et al., 1980)
- Age: age of HoH, a measure associated with farming experience

- Members: number of household family members, potentially a measure of credit risk as larger households presumably have more opportunities to diversify income.
- Land quality: household evaluation of land quality on a scale from very bad (1) to very good (5). The household describes land quality for each plot and this rating is the average, weighted on plot size. Land quality is likely related to credit risk.
- Title: percentage of land on which the household has the land title, a variable potentially important for credit supply
- Savings: reported amount of liquid savings held by the household, a measure likely related to credit risk
- Risk aversion: household willingness to pay to participate in a raffle valued at roughly \$670 with a 10% chance to win. Under expected utility theory, this measure can be used to estimate household risk aversion, which Guirkinger and Boucher (2008) identify as a significant predictor of demand-side credit rationing.

Eighteen percent of the sample reports being credit constrained. Households are matched based on the propensity score generated from the logistic regression. The largest number of matches occur when each constrained household is matched with four unconstrained households. Caliper matching is used with a maximum distance between matched propensity scores set at 20% of the standard deviation of propensity scores. The total number of matched observation is 688 (133 constrained, 555 unconstrained). Table 3.5 shows the matching results. Before matching, unconstrained households have higher-valued homes, a larger percent of titled land, and more liquid savings. Propensity score matching balances the groups in terms of home value and savings, but unconstrained households maintain a significantly larger portion of titled land.

Table 3.6 shows the results of the propensity score matching, comparing those who have credit or report no productive need for it with those who would like but do not have it. Results indicate that access to credit significantly increases the use of fertilizer. Because inputs such as fertilizer markedly contribute to productivity, as shown in Table 3.4, easing credit constraints may increase the earnings potential of households; however, it should be noted that in this sample, gross farm income per hectare is not significantly different between the two groups. This nonsignificant result may be due to the substantial variability and many potential sources of estimation error in household gross farm income.

Table 3.5: Sample means before and after propensity score matching

	Before			Significance (p value)	After		
	Unconstrained	Constrained			Unconstrained	Constrained	Significance (p value)
Home	128.90	106.50		0.021	116.41	107.64	0.34
Education	5.07	4.92		0.712	4.91	4.88	0.943
Age	59.14	59.39		0.338	57.97	58.36	0.402
Members	4.38	4.43		0.494	4.54	4.57	0.592
Land quality	3.59	3.52		0.335	3.56	3.52	0.517
Title	0.67	0.52		0.002	0.65	0.52	0.008
Savings	141.22	44.02		0.037	59.35	46.09	0.72
Risk aversion	27.21	22.14		0.325	23.77	22.03	0.668

Note: Sample means compared with t-tests.

Households in northern Peru tend to own rather than rent land, and a large portion of farm labor is conducted by the household; therefore, this result of credit increasing fertilizer use seems consistent with a hypothesis that credit is alleviating household liquidity constraints (Carter, 1989; Feder et al., 1990; Fletschner et al., 2010). Alternatively, this result may be explained by a hypothesis that credit alters household production toward more intensive, higher risk, higher expected return strategies by transferring production risk to lenders (Giné and Yang, 2009; Stiglitz and Weiss, 1981).

Table 3.6: Effect of credit constraints on production allocations

	Effect	Std. error	95% Confidence Interval
Gross farm income per ha	-485.85	667.34	[-1793.53, 822.39]
Land	-0.21	0.26	[-0.72, 0.31]
Labor	-71.74	37.09	[-144.43, 0.95]
Animals	4.19	9.94	[-15.30, 23.67]
Machinery	-201.64	167.28	[-529.50, 126.22]
Fertilizer	-733.39	339.76	[-1399.30, -67.48]
Pesticide	6.89	73.91	[-137.97, 151.75]

3.4. Relaxing assumptions

In this section, we alter some of the above assumptions to model real world constraints and evaluate the implications for credit and insurance markets. First, we introduce a type of interest rate yield curve where lenders must pay higher rates for short-term funds. This yield curve increases the cost of unexpected borrowing. Second, we model the insurance mechanism specifically as index insurance, which can transfer disaster risk but is prone to measurement error. Finally, we consider the role of index insurance in a scenario in which only a portion of households affected by a disaster default.

3.4.1. Increased short-term borrowing costs

Rather than assuming that the lender has immediate access to international funds (as we do above), suppose that acquiring funds from an international bank is time consuming so that funds arrive the following period. If lenders need funds immediately, they must use the short-term market, which charges an interest rate r_s where $r_s > r$. Each period, the lender must fulfill its debt liabilities. If households fail to repay their loans, the lender either exercises its right on borrower collateral or goes to the short-term markets and borrows at the short-term rate.

As Section 3.2.2 demonstrates, loan products can be developed in a number of ways to transfer risk from households to the lender. From here forward, we use the loan contract with debt forgiveness in the occurrence of a disaster as the illustrative case. Higher short-term borrowing costs for the lender increase the cost of providing debt forgiveness. The actuarially fair interest rate for the loan with a forgiveness clause is $r + p(1 + r_s)$. Household cash flow for this scenario in the second scenario of Table 3.2.

Insurance can add substantial value in this context by reducing the cost of reallocating resources across different states of nature. We consider two options. First, the household could buy insurance at a level equal to the value of the loan. Second, the lender could purchase insurance to manage its cash flow risk and continue to offer households the loan with a forgiveness clause. The insurance, whether purchased by the household or lender, returns household cash flows to those of the perfect markets scenario, see Table 3.2. In sum, under a condition of higher short-term borrowing costs for lenders, insurance reduces the cost of risk transfer by $(r - r_s)pb$.

While we model an additional cost of market disruptions in the form of higher short-term borrowing rates, operational consequences of disasters for lenders may be many. For example studying El Niño risk and credit markets in northern Peru, Collier (2013) notes that natural disasters create loan losses that erode lender capital. In response, lenders tend to reduce the supply of credit following a disaster as they replenish their capital reserves. This disruption comes at a significant opportunity cost of foregone lending that is likely much greater than the increased costs of short-term borrowing. For example, Collier (2013) estimating current exposure predict a reduction in lending of approximately 20% following a severe El Niño.

3.4.2. Index insurance and basis risk

Next, we specify that the type of insurance product offered is index insurance, currently the most common form of insurance used for agricultural production risks in development projects. Index insurance protects against disasters based on a specific measure of the severe event. Commonly, the index is weather data (e.g., rainfall) collected at a weather station. For illustrative purposes, we assume that the weather risk ϕ is perfectly positively correlated with losses ψ .

Households and lenders require different measurements for the disaster event, based on their vulnerability. For households, the event is measured based on readings at the closest weather station ϕ_w . As a result, there is error in the measure as the weather may differ for households from that at the weather station. This measurement error is *basis risk*. The household index $\hat{\phi}_h$ is

$$\hat{\phi}_h = \phi_w. \quad (3.4)$$

For the lender, the event is measured based on readings from a group of weather stations representing the geographic dispersion of its portfolio

$$\hat{\phi}_l = \sum_{i=1}^N g_i \phi_{wi} \quad (3.5)$$

where i denotes the sequence of weather stations and g_i is the proportion of the portfolio associated with each weather station such that $\sum_{i=1}^N g_i = 1$. Because it relies on a greater number of observations, the index used by the lender is associated with lower basis risk than the household index, which is proven here and illustrated empirically in the next section.

Proposition: The index used for the lender is a more efficient estimator than the index used for households. To make a consistent comparison, we use two scenarios:

1) every borrower insures its disaster risk using the household index and this protection is aggregated to the lender portfolio and evaluated as a weighted average based on the portfolio allocation, and 2) the lender insures its portfolio using the lender index. For a given occurrence of weather for households, the weather at the closest weather station can be written as

$$\phi_{wi} = \phi_{hi} + \epsilon_{hi}$$

where ϵ_{hi} is an error term distributed $N(0, \sigma^2)$.

Household index. The expectation for the household index is

$$\mathbb{E}[\hat{\phi}_{hi}] = \mathbb{E}[\phi_{wi}] = \phi_{hi}$$

indicating that the household index is unbiased. The variance of the estimator for a given occurrence of weather for households is

$$\text{var}(\hat{\phi}_{hi}) = \text{var}(\phi_{wi}) = \sigma^2.$$

Let $\hat{\phi}_H \equiv \sum_{i=1}^N g_i \hat{\phi}_{hi}$, the aggregation of the household index to the level of the lender's portfolio. Aggregating the expectation of the household index yields

$$\mathbb{E}[\hat{\phi}_H] = \sum_{i=1}^N g_i \phi_{hi} = \bar{\phi}_h$$

where $\bar{\phi}_h$ is the weighted portfolio average of the weather occurrence across all borrowing households. The aggregated variance is

$$\text{var}(\hat{\phi}_H) = \sum_{i=1}^N g_i \sigma^2 = \sigma^2.$$

Lender index. The expectation of the lender index is

$$\mathbb{E}[\hat{\phi}_l] = \mathbb{E}\left[\sum_{i=1}^N g_i \phi_{wi}\right] = \sum_{i=1}^N g_i \mathbb{E}[\phi_{wi}] = \bar{\phi}_h.$$

Thus, $\mathbb{E}[\hat{\phi}_l] = \mathbb{E}[\hat{\phi}_H]$ and this estimator is also unbiased. The variance of the lender index is

$$\text{var}(\hat{\phi}_l) = \text{var}\left(\sum_{i=1}^N g_i \phi_{wi}\right) = \sum_{i=1}^N g_i^2 \text{var}(\phi_{wi}) = \sum_{i=1}^N g_i^2 \sigma^2.$$

Because $\sum_{i=1}^N g_i^2 \leq 1$, $\text{var}(\hat{\phi}_l) \leq \text{var}(\hat{\phi}_H)$. The index used for the lender is a more efficient estimator than the index used for households. \square

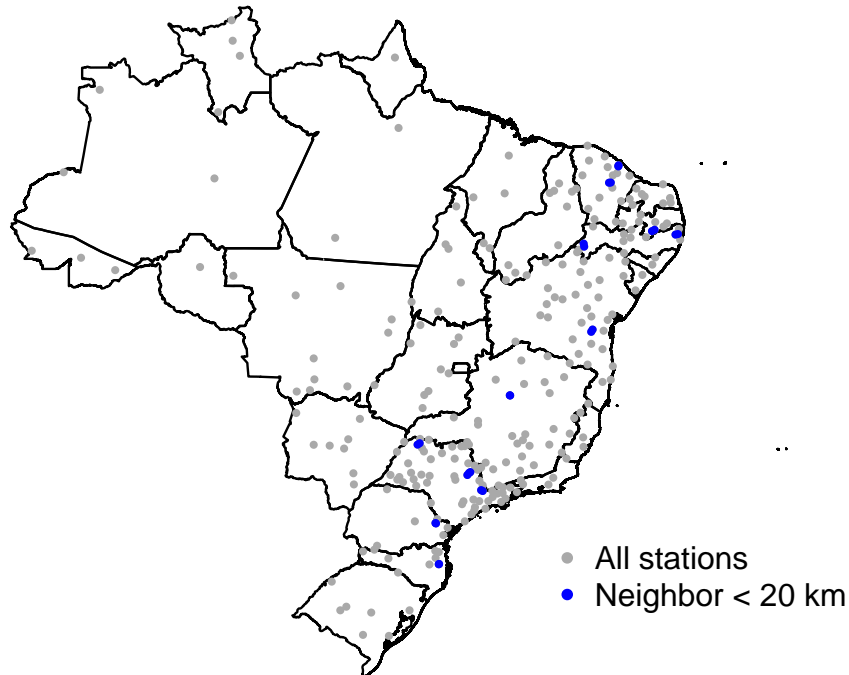
Basis risk illustration from Brazil

We illustrate basis risk using weather station data from the Global Historical Climatology Network. This network reports only three stations for northern Peru, too few to assess the benefits of aggregation using a lender index. Instead, we use data from Peru's neighbor

Brazil. Important differences in terrain and weather patterns limit the generalizability of the specific values of this estimation; however, the principles are universal.

This illustration demonstrates the degree to which rainfall in one location can be approximated by rainfall in another. As an insurer would approximate rainfall at a farmer's land (Point A) using rainfall at the closest weather station (Point B), we attempt to predict rainfall at one weather station (Point A) using rainfall at its closest neighboring weather station (Point B). We use monthly data from January 1980 to December 2000 for 276 stations reporting 37,584 observations. Figure 3.4.2 shows the geographic distribution of these stations and a subset that we use in the analysis below. Median monthly rainfall for these stations is 1.21 m (standard deviation is 1.14 m).

Figure 3.1: Weather Stations



Note: Sample of 276 weather stations reporting monthly rainfall from 1980–2000 and subsample of 25 stations that have a neighboring station within 20 km.

Let ϵ represent the difference in rainfall between two weather stations. Thus, in trying to predict rainfall ϕ at station h , we use rainfall at station w

$$\hat{\phi}_h = \phi_w + \epsilon.$$

We estimate the influence of distance in kilometers on the absolute value of error ϵ (see Table 3.7). Given that insurance is used to manage extremes (e.g., drought or excess rain),

we also examine two subsets of the data: error associated with the lowest 10% of rainfall observations and that with the highest 10%. These models have little explanatory power, indicating many other factors such as topography should be taken into account in designing a weather index. Model results indicate that, on average, each kilometer between a weather station and its nearest neighbor increases the estimation error in monthly measurements by 1 mm.

Table 3.7: Effect of Distance on Rainfall Estimation Error

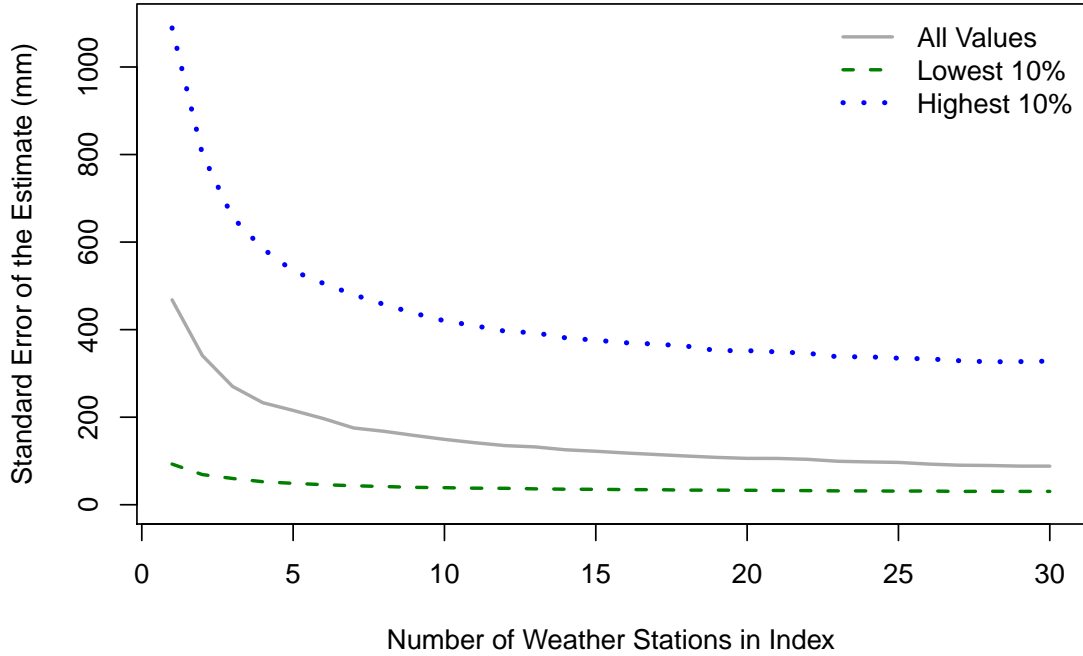
	Full sample			Lowest 10%			Highest 10%		
	Estimate	Std. Error	t value	Estimate	Std. Error	t value	Estimate	Std. Error	t value
(Intercept)	370.95	3.85	96.43	23.06	5.33	4.33	954.83	19.14	49.89
Distance (km)	1.14	0.02	46.18	0.61	0.04	16.85	1.41	0.09	14.97
Resid. std. error	579.9			241.6			919.4		
R squared	0.053			0.070			0.056		
F statistic	2,133			283.9			224.1		
d.f.	37,563			3,773			3,756		

Outcome variable: $|\text{error}(\text{mm})|$

The median distance between weather stations in this sample is 55 km. Since a weather insurance contract is only likely to be written using rainfall data for stations relatively near the insured, we use a subset of the data, only including stations with a nearest neighbor within 20 km, the same requirement the World Bank has used, for example in Malawi and Thailand (Hellmuth et al., 2009). Limiting the data to stations with a nearest neighbor of 20 km or less provides 2,537 observations from 25 stations. Distance is not a significant predictor of error for this subsample (analysis not shown). Mean error for this sample is 0.4 mm, approximately zero, suggesting that our measure is unbiased. The mean of the absolute value of the error, the average magnitude of error is 257.5 mm.

Using the subsample of weather stations with a neighboring station within 20 km, we assess the degree to which the lender index lowers estimation error for differing levels of aggregation. Suppose the lender index comprises x weather stations. To estimate the error of this index, we randomly draw x observations of error ϵ in our sample with replacement and take the mean of these x observations. We repeat this task 10,000 times and take the standard error of the estimate. The household index is a special case in which $x=1$. Figure 3.4.2 shows the results for $x=1-30$. It demonstrates that even small levels of aggregation can reduce error substantially. For example, using observations from five stations rather than one reduces the standard error of the estimate by half for all three cases.

Figure 3.2: Lender Index and Error



Note: Evaluation of the change in the standard error of the estimate as the number of weather stations used to estimate rainfall increases. Figure evaluates for all values; the lowest 10% of values, “drought conditions;” and the highest 10% of values, “excess rain conditions.” All stations in the sample have a neighbor within 20 km.

Implications of basis risk for credit and index insurance

Basis risk has important implications for how insurance is used. Following on the scenario in Section 3.4.1 where the lender faces short-term lending costs, we continue the evaluation of index insurance under the two structures already described, loan forgiveness through 1) household insurance, or 2) insurance purchased by the lender and transmitted to households through the lending relationship. Because both household and lender indices are unbiased, comparisons based on expected value are uninteresting and even misleading. Instead, we propose a stress-test associated with a measurement error of probability q^* , for example a measurement error of one standard deviation below the mean. A disaster occurs and the household and lender indices pay with the associated measurement errors of $-\epsilon_h^*$ and $-\epsilon_l^*$, respectively, underpaying relative to the incurred losses.

For the loan product, the lender offers households a loan with a clause that forgives the interest and principal of the loan if the disaster occurs. Then the lender borrows from the international bank to buy insurance and insures its risk at a sum insured of $(1+r)l$. When the disaster occurs, the lender receives a payout of $(1-\epsilon_l^*)(1+r)b$. To meet its liabilities

to the international bank, the lender borrows on the short-term market $\epsilon_l^*(1+r)b$ due to the basis. Households must repay the lender in period $t+1$ for the amount borrowed on the short-term market. Thus, household cash flow under this scenario is shown in the basis risk stress scenario in Table 3.2. A comparison with the perfect markets scenario shows the cost of basis risk in this context, the amount paid in period $t+2$.

Alternatively, the household fully insures its loan using the household product. The lender wants to prevent household default and so agrees to extend a short-term loan if the insurance pays less than insured household losses. When the disaster occurs, the household receives a payout of $(1-\epsilon_h^*)(1+r)b$. To meet its liabilities to the international bank, the lender goes to the short term market and borrows $\epsilon_h^*(1+r)b$. It then passes this cost to households. By using a household index rather than a lender index, basis risk increases the cost of the disaster for households by $(\epsilon_l^*-\epsilon_h^*)(1+r_s)(1+r)b$. For the Brazil example above, the standard error of the household index can be more than eight times greater than that of the lender index. As a consequence of greater basis risk, households insuring their credit risk will tend to borrow and invest less, slowing development. Households would manage their credit risk at a lower cost by having the lender insure and transmit coverage to households.

3.4.3. Index insurance under limited default

Finally, we model the case in which only a portion of households default when a disaster occurs. Households are unaware *ex ante* whether they will default when the disaster occurs. One explanation for this uncertainty is that it is the result of a diversified production strategy by which households earn income from a variety of activities with differing disaster vulnerabilities. To illustrate, a Peruvian producer grows mangos, selling a portion in local markets and exporting the rest. The producer also sells a handicraft in the local market. This producer is vulnerable to severe El Niño events. Depending on the occurrence of El Niño-related torrential rain, these conditions have the potential to 1) reduce yields, 2) close local markets, and/or 3) destroy roads this producer needs to export.

Given a disaster event of probability θ experienced by households, denoted $\phi_h(\theta)$, a portion of households experience large losses ψ_L and consequently experience a liquidity shortage ($f_{\psi_L} < (1+r)b$). Given the disaster, the probability of any household experiencing large losses is ω . Otherwise, households experience a small level of losses ψ_S . Thus, given

the disaster event, household income can be written as

$$y(\psi|\phi_h(\theta)) = \begin{cases} f_{\psi_S} - rb, & \text{with probability } 1 - \omega \\ f_{\psi_L} - rb - \nu((1+r)b - f_{\psi_L}), & \text{with probability } \omega. \end{cases} \quad (3.6)$$

Suppose the lender requires that all borrowers insure their loans with the household insurance.³ While only a portion of households (ω) would default when the disaster occurs, to prevent default using insurance for households, all households must insure as if they will experience large losses. As a result, household cash flow follows the perfect markets scenario in Table 3.2.

Alternatively, the lender could purchase protection at a level that matches the proportion of borrowers that would default (ω). The expected per-unit cost of providing this coverage for the lender is $\omega p(1+r)$. Household cash flows under this scenario are shown in the final rows of Table 3.2. These results suggest that if lenders require household insurance for their borrowers, that the associated credit risk is over-insured. Over-insuring has the high opportunity cost of reducing household production investments. Alternatively, by the lender purchasing insurance and transferring benefits to households, the cost to households of protecting against disaster-related default risk is reduced by $p(1-\omega)(1+r)b$. This efficiency enhancement increases investment and facilitates household capital accumulation.

As described in Section 3.2.2, the information available to lenders and the structure of incentive compatibility conditions determine how well lenders can identify households in need of loan forgiveness ex post. In cases for which incentive compatibility conditions are extremely onerous for households, e.g., permanently excluding them from credit markets, household insurance may be preferred to lender insurance. This outcome can point to a larger set of credit market problems created by asymmetric information. Thus, while a development practitioner might choose to pursue household insurance to manage disaster-related credit risk, in some cases, resources may be better used to address these information problems (e.g., by strengthening underwriting and monitoring practices or expanding credit bureaus). If so, such an approach could increase the feasibility of more efficient disaster risk management approaches such as the lender mechanisms described above.

³For example, lenders might adopt this policy if households are unable to collateralize loans and the lender wants to offer a lending interest rate with a lower face value. In this case, insuring is a transaction cost of borrowing. Several index insurance pilots have tested lending with mandatory insurance for households.

Distressed land sales illustration

Information on household level loan performance was not collected in the 2003 sample; however, households did report distressed land sales. Households were asked if during the past five years, they sold or lost land. Households who had sold land were asked for their reason and could chose among 11 provided responses (e.g., to buy a house in the city, loss of a family member, repay a loan) or provide their own. While it was not one of the provided responses, the most frequent response was that households sold land as a consequence of the 1998 El Niño.

We evaluate households who sold land due to adverse events, in other words, excluding responses not associated with risk coping (e.g., I sold land because I have so much). Eighty four out of 1,071 households (8%) surveyed reported selling land due to adverse events within the previous five years. Table 3.8 provides their motivation for these sales and the frequency with which it was reported.

Table 3.8: Reasons identified for distressed land sales

Frequency	Reason
45	Because of El Niño
14	To repay debt to banks
9	Insecure land tenure
6	Head of household became sick and could no longer cultivate it
4	Sick family member
2	Death in the family
2	To repay debt to a commodity buyer
1	Household lost its inheritance
1	There was insufficient water

Distress land sales is a coping response that can undermine future household earnings potential and seems to suggest a similar level of household duress as what might lead a household to default on its loans. In this context, we attempt to model distressed land sales using household information. If such a model had strong explanatory power, it would suggest that lenders may be able to target household insurance to households that were likely to default following a disaster. The model includes the following household characteristics:

- Age: age of the head of household
- Gender: sex of the head of household
- Education: years of schooling completed by the head of household

- Members: number of people in the household
- Net income: household reported net income in the previous 12 months
- Agricultural income: percent of total income derived from agriculture
- Agricultural labor: percent of total household labor devoted to agriculture
- Land: amount of land owned by the household (in hectares)
- Title: if the households has a title for its land
- Land quality: household evaluation of land quality on a scale from very bad (1) to very good (5). The household describes land quality for each plot and this rating is the average, weighted on plot size.
- Livestock value: reported value of stock animals
- Credit (formal, semiformal, informal): whether the household has used credit in the previous 12 months, binary variables. Informal credit describes borrowing from family, friend, or a moneylender; semiformal credit includes borrowing from a nongovernmental organization, unregulated financial institution, or agricultural cooperative; formal credit describes borrowing from a regulated financial intermediary.
- Niño production loss: percent of agricultural production household reports losing due to the 1998 El Niño.
- Land slope: household report of land grade. Possible responses are “plain,” “small slope,” “moderate slope,” or “steep slope.” The response used is for the household’s primary plot.
- Irrigation: type of irrigation used by household. Options include “gravity to furrows,” “pump to furrows,” “aspersion,” or “none.” Irrigation is not only important for reducing the risk of inadequate rainfall, but for El Niño-related flooding, irrigation canals can provide drainage for excess water.
- Districts: These are government boundaries typically smaller than U.S. counties. For example, Colán is 159 km². Districts with less than 10 households were excluded.

For all categorical variables, the most frequent response was chosen as the reference group.

Table 3.9 presents the model results. Households that have higher incomes, better land quality, a smaller proportion of their income from agriculture, and larger livestock holdings were less likely to engage in distressed sales. In this sample, better reported land quality is not significantly correlated with income. Thus, land quality seems to be an indication of reduced production risk. Livestock holdings are also unrelated to net income in this sample; we interpret the role of livestock holdings as a capital stock that could be sold instead of land to cope with an adverse event. The model reports that distressed land sales were significantly less likely in one district, Cura Mori. This district is in an agricultural area

about 20 km from Piura, the largest city in the region, suggesting that households in this district may have more coping alternatives available to them than remote households.

The model correctly predicted 56% of distressed land sales with a false positive rate of 22%. It is worth noting that this is in-sample prediction; correct out-of-sample identification rates are likely to be much lower. Moreover, predictive ability decreases with time as modeled relationships change. At the writing of this paper, severe El Niño has not occurred in over 15 years, a period over which many economic, demographic, and technological changes have occurred. Thus, while such a model seems useful in identifying characteristics that predispose households to distressed land sales, we believe a lender program that uses such an approach to target specific households and require them to insure would operate with little success.

Table 3.9: Logit predicting distressed land sales.

	Estimate	Std. Error	z value	Pr(> z)	
(Intercept)	2.82	1.04	2.73	0.006	***
Age	0.01	0.01	0.67	0.502	
Gender (male=1)	0.33	0.56	0.58	0.561	
Education	-0.02	0.04	-0.60	0.547	
Members	0.01	0.04	0.42	0.677	
Net income	-3.91E-05	0.00	-2.51	0.012	**
Agricultural income (% of total)	0.84	0.42	1.98	0.047	**
Agricultural labor (% of total)	0.14	0.51	0.27	0.784	
Land (ha)	-0.12	0.08	-1.56	0.118	
Title (yes=1)	0.64	0.45	1.42	0.157	
Land quality	-1.45	0.21	-6.92	0.000	***
Livestock value	0.00	0.00	-2.25	0.025	**
Credit, formal	-0.40	0.48	-0.82	0.411	
Credit, semiformal	-0.85	0.73	-1.16	0.244	
Credit, informal	0.12	0.29	0.41	0.684	
Niño production loss (% of total)	-0.68	0.35	-1.96	0.050	*
Land slope (reference: plane)					
Small slope	-0.42	0.69	-0.61	0.541	
Moderate slope	-0.02	0.43	-0.04	0.967	
Strong slope	-0.08	0.33	-0.24	0.810	
Irrigation (reference: gravity to furrows)					
Aspersion	1.71	1.27	1.34	0.180	
Pumping to furrows	-1.06	0.78	-1.35	0.177	
None	0.56	0.74	0.76	0.447	
District (reference: Marcavelica)					
Bellavista de la Union	-0.63	0.54	-1.19	0.236	
Buenos Aires	-0.24	0.46	-0.51	0.611	
Castilla	-0.33	0.75	-0.44	0.659	
Catacaos	-0.66	0.53	-1.25	0.211	
Colan	-5.36	263.80	-0.02	0.984	
Cura Mori	-2.30	0.77	-2.97	0.003	***
Ignacio Escudero	-0.20	0.68	-0.29	0.772	
La Arena	-0.06	0.85	-0.07	0.942	
Querecotillo	0.02	0.49	0.04	0.966	
Salitral	0.17	0.69	0.25	0.800	
Tambo Grande	0.10	0.58	0.18	0.858	

Note: * indicates $p < 0.1$, ** indicates $p < 0.05$, *** indicates $p < 0.01$

3.4.4. Summary

Section 3.4.1 indicates that in the presence of high short-term borrowing costs, insurance can add value to credit markets by managing state-contingent risks. Whether the lender or household insures lending risk, the household experiences the same cash flow. Sections 3.4.2 and 3.4.3 demonstrate that managing disaster-related credit risk through lender-level index insurance is more efficient than through household-level index insurance. When lender-level index insurance is used, the benefits to households are transmitted through the lending relationship. These efficiency gains are due to 1) reduced basis risk, and 2) a lower sum insured needed to manage disaster-related risk for lender-level indices. These efficiency gains suggest a long-term role for lender-level index insurance, even as insurance markets for households develop that allow them to more comprehensively manage disaster risk.

3.5. Conclusion

Insurance markets addressing natural disaster risk have the potential to serve many stakeholders with a variety of needs; however, developing sustainable markets is a process. This paper demonstrates that lender-level index insurance has the potential to benefit households by increasing investment opportunities and facilitating economic growth. Moreover, lender-level index insurance can provide comparable or greater benefits to households than household-level index insurance for managing credit risk. As a result, insurance for FIs seems to be an attractive and meaningful first step in regions where disaster risk constrains access to finance.

In some cases, asymmetric information is likely to create conditions where household insurance is preferred over lender insurance. For example, consider a credit market with many lenders but no credit bureaus. In this context, lenders have limited information on new borrowers and fewer opportunities to use future access to credit as an incentive for repayment. In this case, household insurance could act as a signal to lenders. Managing credit risk with household-level insurance can thus be understood as a “second-best optimal” outcome due to market failure, bringing along inefficiencies not only documented here but in the vast literature on asymmetric information. Given that lenders must develop business models to overcome asymmetric information to lend sustainably in the first place, we contend that cases for which disaster-related credit risk is better managed with household insurance than lender insurance are exceptions, not the rule.

Household vulnerability extends beyond credit risk and so sustainable insurance markets that provide protection against disaster-related asset losses and income fluctuations are an important long-term goal. Household insurance designed to protect production loans should not be conflated with insurance products to protect household well-being against disasters. Insurance for loan protection will tend to be structured around growing conditions for specific crops for which households are borrowing to plant (e.g., see GFDRR, 2011). Given the diversified livelihood strategies of households, protecting household well-being is likely better addressed through disaster-coverage akin to life insurance, coverage that focuses on severe events that can affect households for a generation.

In many regions, a significant intermediate step toward viable household insurance markets might be extending disaster insurance to the asset and business interruption risks of vulnerable small and medium enterprises (SMEs). SMEs employ around 45% of the labor force and generate 30% of GDP in developing countries (Financial Inclusion Experts Group, 2010), and their vulnerability to natural disasters is well documented (Alesch et al., 2001; Tierney, 1995; Zhang et al., 2009). For example, according to the Institute for Business & Home Safety (2007), 25% of US SMEs close after experiencing a natural disaster. SME vulnerability in developing and emerging economies is likely greater.

Many factors affect the implementation of financial risk management mechanisms for disasters. For example, regulation limits the activities of lenders and insurers in many jurisdictions. These and other implementation considerations are quite important for real-world applications and affect the structures of those products. We do not intend to dismiss or downplay these complicating factors. Rather, we intend to highlight that many of the benefits of using household-level insurance to manage credit risk may already be provided through credit contracts and so suggest that the most effective means to enhance financial inclusion through index insurance may be by strengthening the ability of lenders to offer these benefits through lender-level insurance.

Chapter 4. Inclusive Finance and Systemic Risk Policy

4.1. Introduction

This paper considers the influence of international investors and prudential banking standards on the management of systemic risk among financial intermediaries (FIs) providing inclusive finance in developing and emerging economies. Inclusive finance describes the provision of financial services to the poor and other marginalized groups typically underserved by financial markets. While inclusive finance intermediaries (IFIs) tend to be evaluated with protocols created for developed country banks, they differ dramatically from those counterparts due to the innovative steps IFIs take to reach markets traditionally thought inviable. Additionally, the context of developing countries alters the systemic risks to which IFIs are vulnerable, the three most important of which are price instability such as inflation, political intervention and instability, and natural disasters. Because of the strong, negative relationship between vulnerability and development, public and private policies that do not support the management of systemic risks migrate investment toward the most resilient poor, those that have the greatest chance of participating in traditional financial markets.

Regarding banking regulation and supervision, overwhelmingly developing and emerging economies have implemented the Basel Accords to manage systemic credit risks; however, these standards are limitedly effective for IFIs because they differ so greatly from the FIs for whom they were designed. Two significant limitations of this approach emerge. First, as applied to IFIs, the Basel Accords are insensitive to the risks of IFIs and so do not have the capacity to align private and public interests in risk taking. Using a sample of over 900 IFIs, we demonstrate that regulation does not meaningfully influence the capital reserves held by IFIs. Second, the Accords motivate IFIs to rely on minimum capital requirements to manage systemic risk, a management strategy that is costly but limitedly effective when compared to alternatives. Because IFIs take on substantial risk, a management strategy heavily focused on reserving notably reduces the size of IFIs, limiting the expansion of credit markets and the motivation of IFIs to mobilize savings deposits. Moreover, when

systemic shocks occur, reliance on capital reserves leads lenders to contract credit after a severe event. For events such as natural disasters, this approach causes credit markets to shrink precisely when communities need them to grow to finance rebuilding and recovery. In this context, the limited capacity to manage disasters leads many IFIs to avoid lending to vulnerable groups, perpetuating financial exclusion.

In the absence of risk-sensitive regulation, the market motivates systemic risk management based on its interests. Our results show that higher debt financing costs lead IFIs to hold larger capital reserves. A handful of development banks and socially oriented investment funds guide international investments in inclusive finance. Many of these investors also rely on developed country credit risk protocols to assess developing country IFIs. While their objective is to do good, their scope is more limited than that of regulating supervisors as they must balance social and financial returns. As a result, these investors face difficulty finding investment-worthy opportunities, leading them to concentrate funds in a small number of IFIs in a few countries. Because these investors are few in number and reside in influential jurisdictions in Western Europe and North America, through collaboration they may have the greatest ability to change both private and public policy approaches to inclusive finance.

Systemic shocks can be better managed. We recommend a set of banking policies for disaster risk that, if adopted by regulating supervisors and the market, are likely to increase the outreach and sustainability of inclusive finance in many regions. Rather than relying so heavily on capital reserves, supervision that recognizes the benefits of diversification and motivates, when possible, IFIs to transfer severe systemic risks internationally would better serve public and private interests.

This paper is structured as follows. First, we discuss the Basel Accords and their widespread adoption. Second, we review the characteristics of inclusive finance in developing and emerging economies and the systemic risks to which it is vulnerable. We give special attention to natural disaster risk because it is almost entirely overlooked in developed country assessments of risk and strategies used by IFIs tend to increase their vulnerability to disasters. Third, we examine the determinants of the capital reserves of IFIs. Fourth, we delve into the limitations of current regulatory standards. Finally, we offer recommendations for improving supervision and enhancing the risk management strategies of IFIs.

4.2. The Basel Accords and international standards

International banking standards are guided by the Basel Accords, a regulatory framework intended to improve the quality of banking supervision and create continuity across jurisdictions. The Basel Committee includes members from 27 middle and high income countries (Basel Committee on Banking Supervision, BCBS, 2011a). Public intervention is intended address the negative externalities of bank failure on the real economy (BCBS, 2011b).

The Basel Accords are primarily focused on managing systemic losses from shocks such as a macroeconomic crisis through minimum capital requirements. These requirements are a balance sheet identity in which a certain amount of capital (e.g., equity) must be associated with each asset bearing risk that is held by the FI. These requirements create a buffer against insolvency as portfolio-level losses reduce capital.

The Basel Accords were developed for large developed country banks and are updated to address the evolving risks faced by these banks and the shortcomings of the previous versions of the Accords. For example, Basel II codified the methods the most advanced international FIs used to manage risk (Rochet, 2005; Santos, 2001), and Basel III is a response to the evolution of the financial sector in developed countries (Blundell-Wignall et al., 2010). Financial services in developed countries are marked by an increased integration with capital markets, changing the structure of assets, liabilities, and off-balance sheet obligations and the associated risks.

While the Basel Accords may be officially intended for large, international banks, they are being implemented much more broadly. One hundred, thirty-seven of the 143 jurisdictions (96%) responding to the World Bank's Banking Regulation and Supervision Survey reported that they were using either Basel I or II at the end of 2010. Some of the largest banks in developing and emerging economies are heavily participating in developed country financial markets; however, many FIs in developing and emerging economies are implementing new technologies and approaches in retail banking and FI financing that allow them to reach economic sectors and regions traditionally under-served by financial markets. This inclusive finance market is not only distinct from traditional banking but vastly distinct from developed country financial markets, creating questions about the suitability of a unified banking code.

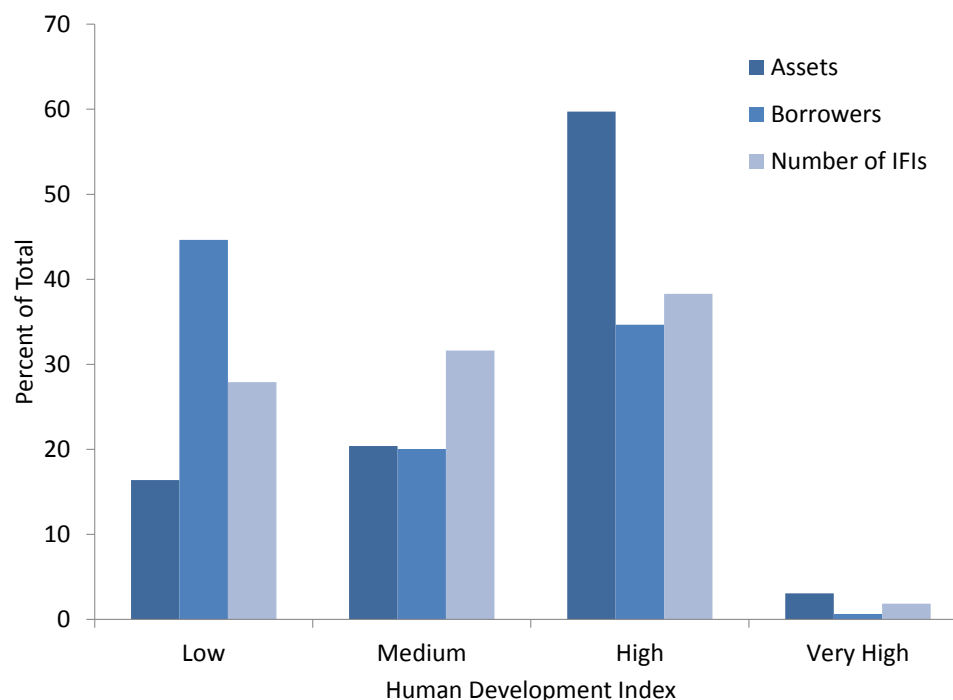
4.3. Inclusive finance in developing and emerging economies

This section highlights some of the characteristics of inclusive finance in developing and emerging economies that distinguish it from traditional retail banking in developed countries. It is divided into three parts. First, we describe strategies that IFIs use to overcome problems of information, delivery, and contract enforcement that have precluded access to financial services previously. Second, we note the evolution in international investment in inclusive finance, which has increased the volume of funding but is highly concentrated. Third, we discuss systemic shocks that are a greater risk in developing and emerging economies and are exacerbated by the operational approaches and financing structures of IFIs.

Inclusive finance is a big sector. For the year of 2011, 1,171 IFIs voluntarily reported to MIX Market (2013), a website dedicated to providing data and research on inclusive finance providers. These IFIs control total assets of \$109 billion and serve 60 million borrowers. As shown in Figure 4.3, they almost exclusively operate in developing and emerging economies, countries ranking as low, medium, or high on the Human Development Index (HDI). The HDI measures health, education, and living standards and divides countries into low, medium, high, and very high categories (United Nations Development Programme, 2013). These four categories are relatively even in terms of numbers of countries. Countries with “high” HDI rankings often fall in the World Bank category “upper-middle-income economies” and include some of the largest IFI markets such as Peru, Bosnia and Herzegovina, and Azerbaijan.

These IFIs are a diverse group. For some, inclusive finance may comprise only a small portion of their portfolio (an IFI in Kazakhstan reports an average outstanding loan value of \$29,000); others are highly specialized nonprofits (an IFI in Indonesia reports an average outstanding loan value of \$34). Roughly half are regulated (56%), but regulated IFIs control 88% of total assets in the sample. Legal status is mixed and reported in Table 4.1. While inclusive finance covers too many countries, people groups, geographic regions, economic sectors, financial products, business models, lending strategies, technologies, etc., to be neatly categorized, we provide a reference point for readers that we believe is mostly true most of the time and helps illustrate the challenges and risks facing this sector.

Figure 4.1: Inclusive Finance Presence by Country Development Category



Note: Percentage of assets held, number of active borrowers, and number of inclusive finance intermediaries organized by a country's 2011 HDI category.

Table 4.1: Legal status of MIX Market sample

Legal Status	% of Sample
Bank	9
Credit union & cooperative	18
Nonbank financial intermediary	33
Nongovernmental organization	34
Rural bank	4
Other	2

4.3.1. Lending model

The vast majority of inclusive finance has been microfinance, which is marked by overcoming the transaction costs of providing small-value financial services in data poor environments. Lending is particularly difficult. Moral hazard (e.g., due to a lack of collateral), high administrative costs relative to loan value, and incomplete information regarding borrower quality (e.g., due to a lack of formalized credit scores) make traditional lending infeasible

with many clients demanding microloans. Special arrangements such as group lending, frequent repayments (e.g., weekly loan payments), and other mechanisms help IFIs overcome information problems and allow for (potentially) profitable lending to these clients (Armendáriz and Morduch, 2011). Borrowers are willing to continue to repay their loans as it facilitates access to credit in the future. By demonstrating the ability to repay over time, these borrowers can obtain lower interest rates and larger loans (Baydas et al., 1997).

Agricultural lending is another important area of inclusive finance. The higher prevalence of farming in developing and emerging economies increases demand for agricultural loans, especially microloans. Farming creates cashflow constraints that preclude certain microlending structures (e.g., weekly payment) and increases IFI exposure to systemic risks due to weather and commodity price volatility. Information needs are high for agricultural loans. Beyond differences inherent to borrowers, land quality and production strategies can greatly affect credit risk. Agricultural lenders often hire agronomists and maintain small, decentralized offices near farmer fields to improve monitoring.

Because microlending and agricultural lending are built on information developed from long-term relationships, IFIs providing these services can most easily expand in their region of current operations. These lenders often employ loan officers from the area where they will be lending due to their knowledge of local communities (Baydas et al., 1997). Opening an IFI branch in a new region can be quite daunting as an IFI has little or no information about potential borrowers in that region. Thus, information challenges and costs motivate portfolio concentrations in regions and economic sectors for which they have developed expertise.

4.3.2. International investments and inclusive finance

Inclusive finance is changing quickly due to the rapid growth of international investments. Cross border funding has grown from \$2 billion in 2005 to \$25 billion in 2011 (Consultative Group to Assist the Poor, CGAP, 2012). Investors are extremely concentrated. Providing over half of total investments, the largest investors are development banks such as KfW in Germany and the International Finance Corporation of the World Bank. Of the development banks, five provide over 70% of cross-border funding (CGAP, 2011a). An increasing amount of investments, currently half of all international investments, are being allocated through microfinance investment vehicles, funds intending to generate both financial and social returns. Blue Orchard, Oikocredit, and responsAbility are some of the largest asset

managers. The top 10 investment funds account for 70% of assets under management; all 10 are located in the Netherlands, Switzerland, or Belgium (CGAP, 2011a).

While cross-border funding in inclusive finance has grown quite rapidly, asset managers are finding it increasingly difficult to place funds. Debt investments accounted for about 60% of investments, equity about 13% (CGAP, 2011b). The limited risk capital (such as equity) of IFIs is constraining financial service expansion, yet the pool of IFIs deemed investment-worthy, especially for equity investments, is quite small. As a result, investors are “aggressively competing” to fund a small number of IFIs (MicroRate, 2011). Ten countries, representing 100 million people in all, receive 60% of cross-border debt financing. Half of all foreign debt is allocated to 25 IFIs, the remaining divided among 500 IFIs (CGAP, 2011a).

Summarizing, the Basel Committee notes that compared to FIs in developed countries, IFIs tend to “have less diversified loan portfolios, funding sources and geographic scope, making them more vulnerable to adverse economic conditions at the local level” (BCBS, 2010, p. 20).

4.3.3. Systemic credit risks in developing and emerging economies

Three systemic risks emerge as particularly important from a developing country context: price instability, political instability, and natural disasters. Many other aspects of a jurisdiction such as contract enforcement influence the effectiveness of credit markets, some of which the business models of IFIs were explicitly developed to overcome. Those business models do not tend to have the capacity to manage systemic shocks, severe, infrequent events that represent existential threats to IFIs.

Price instability such as inflation is greater in magnitude in developing and emerging economies and contributes to both interest and exchange rate risks. The strong linkages between banking and monetary policy make monitoring and managing price instability a priority for developed countries, increasing the capacity of developing and emerging economies as well. For example, exchange markets allow FIs to hedge these risks, and the Basel Accords provide guidelines that are relevant to IFIs. Relatively new firms such as MFX Solutions are creating opportunities for IFIs to hedge currencies not traded in exchange markets. We measure price instability using the maximum level of annual inflation in each jurisdiction calculated from the consumer price index using data from 2002–2011 (Fund, 2013). We exclude Zimbabwe from the inflation data.

developing and emerging economies are more vulnerable to political risk. Political risk is a broad, nebulous category, ranging from regime changes to politically motivated interference in the private sector. For domestic FIs, severe political events may create macroeconomic crises from which these firms cannot diversify. For international investors, insurance for political risks is available, for example from the World Bank. Another example of political risk to the inclusive finance sector is payment holidays supported by politicians in which borrowers decide not to repay their loans as a form of protest (CGAP, 2010). We measure political risk with two variables from the 2011 World Governance Indicators: 1) Political Stability and Absence of Violence, which estimates the likelihood that the government will be destabilized or overthrown, and 2) Government Effectiveness, which estimates the quality of civil services and their independence from political pressures (Kaufmann et al., 2010). Countries are scored on these governance indicators using a scale with a minimum of -2.5 and a maximum of 2.5.

Finally, developing and emerging economies are more vulnerable to natural disasters. Natural disaster risk is given very little attention in developed country standards. The Basel Accords treat natural disasters as an operational risk, suggesting that the Committee's greatest concerns about these events pertain to the destruction of physical property, management information systems, or lifeline services such as electricity that might impede business. While natural disasters may disrupt operations, their effect on credit risk tends to be the primary threat to IFIs (Collier and Skees, 2012). Because natural disasters have been given so little attention in the banking sector, we highlight this systemic risk, discussing a number of reasons why developing and emerging economies tend to be more vulnerable to these events. We measure natural disaster risk with two variables: 1) the average proportion of the population affected annually by natural disasters, and 2) the average annual economic damage of disasters as a percent of GDP, using data for 1995–2010 from the Emergency Events (EM-DAT, 2013).

Table 4.2 illustrates the relationship of each of these variable with development using the HDI development categories. Values reported in the table are the averages across jurisdictions in each category of development.

Natural disasters and developing and emerging economies

Disaster vulnerability in developing and emerging economies is a consequence of both the more frequent occurrence of hazards as well as the context (demography, geography, infras-

Table 4.2: Systemic Risks by Development Category

	Low	Medium	High	Very High
Inflation (%)	21.62	15.94	16.83	6.95
Political Stability	-0.90	-0.18	-0.13	0.84
Government Effectiveness	-0.94	-0.39	-0.02	1.28
Disasters, Affected (% of Population)	4.42	6.90	1.91	0.42
Disasters, Economic Damage (% of GDP)	20.67	3.85	4.94	2.66

structure, etc.). First, developing and emerging economies tend to be regions where severe weather is more frequent such as tropical regions, which experience higher temperatures but also greater rainfall variability (Brown and Lall, 2006). Rainfall is often concentrated in a single season, increasing the risk of drought, excess rain, and flooding.

Second, their economies participate in at-risk sectors such as agriculture. Agriculture accounts for 22% of GDP and 53% of the labor force for countries ranked “low” on the HDI, compared to 2% of GDP and 5% of the labor force for “very high” HDI countries.¹

Third, underdeveloped financial services contribute to higher vulnerability. Households and firms in developing and emerging economies are dramatically less likely to be insured (Swiss Re, 2012). Instead, households tend to be more interdependent, especially in rural communities. Some communities develop complex risk sharing arrangements that facilitate management of idiosyncratic risks; however, these arrangements tend to break down during natural disasters as many individuals in the community need help concurrently (Fafchamps and Lund, 2003; Townsend, 1994).

Fourth, many cities in developing and emerging economies are struggling to accommodate rapid urbanization, leading the urban poor to settle undesirable land such as in low-lying areas and steep hillsides (Stern, 2008). These communities are also vulnerable due to members residing in less durable structures as well as a lack of public sanitation and other services.

Finally, the outreach of social safety nets is often limited. While international aid agencies partially offset insufficient developing country relief budgets, aid can be slow. For example, Lentz et al. (2013) estimate emergency food aid shipments arrive over five months, on average, after aid is requested.

Vulnerability to disasters is expected to increase due to the interplay of climate change and evolving demographics in developing and emerging economies (Samson et al., 2011).

¹From World Bank (2012) and HDI (2012) data

Developing countries tend to be in regions that will be most affected by changing climate, those with higher temperatures and more variable rainfall (Stern, 2008). Extreme events are expected to occur more frequently (Nicholls et al., 2007). Population growth will increasingly strain natural resources. The poor are expected to be most severely affected because not only are they currently the vulnerable but their capacity to adapt is most limited. Because the poor are a key demographic for inclusive finance, natural disaster vulnerability will increase for IFIs.

Implications of disaster risk for IFIs

The heightened vulnerability of households and firms are aggregated in the portfolios of IFIs. Moreover, the arrangements needed to serve poor clients such as lending without collateral increase solvency risk during a crisis. Disasters can create both asset losses and liquidity shortages for IFIs. For deposit-taking FIs, liquidity shortages occur due to depositors withdrawing their funds to manage the disaster, borrowers failing to repay loans, and an increased prevalence of bank runs. Liquidity risk represents a relatively greater precipitant of banking crises in some developing and emerging economies due to a history of liquidity shortages and bank runs, lack of credible deposit insurance, currency mismatches, lack of liquid financial markets, and inability of the central bank to act as the lender of last resort (Tanveronachi, 2009).

Disasters can lead to IFI asset losses as problem loans are written down or written off. These losses destroy risk capital, which can quickly make IFIs over-leveraged or insolvent. For example, Caprio and Klingebiel (1996) cite drought as a precipitant of banking crises in Kenya (where eight FIs and one mortgage lender were liquidated from 1986-1989) and Senegal (where six FIs were liquidated and three were restructured and recapitalized from 1988-1991). IFIs may also be vulnerable to contagion. Because obtaining better access to credit in the future is the repayment incentive for some borrowers, doubts regarding the long-term viability of an FI reduce incentives for these borrowers to repay loans (BCBS, 2010).

Limited access to capital reduces opportunities for managing a crisis. IFIs that are heavily financed by international investors can also be vulnerable to liquidity and capital shortages due to investor concentration. International investors face an information problem regarding the solvency of affected IFIs and so may be unwilling to reinvest. IFIs that are neither liquidated nor fully recapitalized must pursue a slow process of deleveraging by

originating fewer loans and building equity through retained earnings (Peek and Rosengren, 1995). Thus, as IFIs shrink to align their assets with their smaller capital bases, communities can enter a credit crunch at a moment when credit is greatly needed for relief and recovery (Collier and Skees, 2012). For example, one year after an earthquake in Indonesia in 2010, affected IFIs tended to have higher rates of nonperforming loans than before the earthquake and negative portfolio growth (Microfinance Innovation Center for Resources and Alternatives, MICRA, 2011). The sunk information costs IFIs invest in their borrowers and prevalence of uncollateralized loans for some IFIs can change the way they respond to borrowers, restructuring loans with protracted terms that extend the effects of the event for years in local communities (Collier et al., 2011). Thus, volatility in banking capital has the potential to create cyclical access to credit in local communities. Moreover, the *risk* of these systemic shocks can be sufficient to prevent IFIs from developing credit markets in vulnerable regions and economic sectors.

Implication of IFI vulnerability for economic growth

Recent macroeconomic research suggests that the resilience of a country's financial sector is particularly relevant to limiting the economic consequences of natural disasters. Severe disasters tend to negatively affect growth when losses exceed a country's capacity to reconstruct following the event (Noy, 2009; Loayza et al., 2012; von Peter et al., 2012; Hallegatte et al., 2007). This reinvestment capacity is positively associated with development indicators such as literacy rates, income per capita, and institutional quality. The risk of a disaster overwhelming a country's capacity to reinvest is also greater in smaller countries where opportunities to diversify are limited (Noy, 2009). For example, the 2010 earthquake in Haiti generated losses equal to 173% of GDP (U.S. Department of State, 2011). Losses from Hurricane Mitch in Honduras were about 73% of GDP (Inter-American Development Bank, 2000). Hurricane Hugo caused losses to Montserrat of about 500% of GDP (World Bank, 1998). In contrast, in the U.S. losses from Hurricane Katrina were 0.6% GDP, but in absolute terms were greater than the losses from the Haiti earthquake and Hurricanes Mitch and Hugo combined (Pielke et al., 2008).

Noy (2009) finds that the level of domestic credit is positively associated with reinvestment capacity, but the size of a domestic stock market is not. This result suggests that capacity to reinvest for micro, small, and medium enterprises in affected communities may

be especially important for economic recovery from a disaster, making IFI vulnerability a consequential public policy issue.

4.3.4. Inclusive finance summary

Because of their lending models, financing structures, and presence in developing and emerging economies, IFIs face markedly different risks than traditional retail banks in developed countries, much less large, international banks. The remainder of this paper explores the implications, empirical and theoretical, of governing IFIs with public and private risk management standards developed for the world's largest banks.

4.4. Determinants of IFI capital reserves

Given the importance supervisors and investors place on capital reserves, we examine those of IFIs reporting to MIX Market. Banks tend to hold capital reserves in excess of minimum requirements to avoid falling below regulated minimums with those managing riskier portfolios holding larger buffers (Ediz et al., 1998; Rime, 2001). Using data from 912 IFIs for 2011, we evaluate the capital-to-asset ratio, the proportion of equity to total assets for each IFI. This ratio is an important indicator of risk that overcomes the data limitations that preclude calculating regulatory capital and weighting assets based on risk, necessary steps to identifying capital ratios. The mean capital-to-asset ratio in the sample is 34% (the median is 26%).

4.4.1. Model Estimation

We use a beta regression to estimate the model because the capital-to-asset ratio lies on the standard unit interval (0,1). Using linear regression in this context risks introducing heteroscedasticity because dependent variable values tend to cluster and avoid the upper and lower limits (Ferrari and Cribari-Neto, 2004).

We estimate the model including variables describing IFIs and their environment. Unless otherwise specified the data are provided by MIX Market:

- Size and financial performance: assets, return on assets (ROA), ratio of financial expenses to assets
- Structure: average loan balance per borrower as a percent of gross national income (GNI) per capita, regulated (yes, no), legal status

- Portfolio quality: portfolio at risk (PAR) greater than 90 days, ratio of loan writeoffs to loan portfolio value, ratio of loan loss provisioning to assets
- Systemic risks: inflation, political stability, government effectiveness, and the number of people affected and economic damages from natural disasters, as described in Section 4.3.3
- Jurisdiction: regulatory quality and region
 - Regulatory quality: a measure of the effectiveness of governments to develop regulations and policies that promote private sector development, using 2011 data from the World Governance Indicators

For detailed definitions and more information on these variables, we refer readers to the original databases.²

This model is a variable dispersion beta regression with a logit link. Parameters are estimated through maximum likelihood. The logit link allows for interpretation of estimation coefficients as log odds ratios. We use the methodology for beta regression outlined in Cribari-Neto and Zeileis (2009), the results of which are shown in Table 4.4.2.

The beta regression originally proposed by Ferrari and Cribari-Neto (2004) assumes a constant precision parameter, which describes the dispersion of the dependent variable. Simas et al. (2010) show that a more general model in which the precision parameter is allowed to vary reduces estimation bias. Given the large size differences of IFIs in the data set, the total assets managed by the IFI at the 10th and 90th percentiles, respectively, are \$827,629 and \$165,459,216, we allow the precision parameter to vary based on the log of asset holdings. A likelihood ratio test demonstrates that this second estimation, which allows for variable dispersion, provides a better fit and so is used for the analysis, see Table 4.3.

Table 4.3: Likelihood ratio test

	#Df	Log Likelihood	Df	χ^2	$\Pr(> \chi^2)$
Beta regression	26	299.06			
Variable dispersion beta regression	27	321.79	1	45.463	0.00

²EM-DAT: www.emdat.be/criteria-and-definition; International Monetary Fund, International Financial Statistics www.imf.org/external/data.htm; MIX Market: www.mixmarket.org/about/faqs/glossary; World Governance Indicators www.govindicators.org

4.4.2. Results

Table 4.4.2 summarizes estimation results. We interpret risk as the primary driver of many of the results. First, the capital-to-asset ratio is negatively associated with portfolio quality as measured by the proportion of the loan portfolio written off, though not by provisioning levels or PAR. FIs often have flexibility to lower PAR and provisioning through loan restructuring, limiting the information these commonly used metrics provide. Second, the capital-to-asset ratio is negatively related to the size of the FI. Presumably as an FI grows, it reduces its geographic and economic sector concentrations through diversification, allowing it to operate with a relatively smaller capital base. Third, the positive association between ROA and the capital-to-asset ratio is likely due to the strong positive relationship between risk and return. Thus, it seems to be an additional indication that the risk measures do not fully account for the contribution of risk to capital reserve allocations. These risks are likely broader than credit risks and include a number of operational risks that are difficult to measure in a global database such as strength of institutional governance and integrity of management information systems.

Regarding the risks of price shocks, political instability, and natural disasters, the results suggest that IFIs do not take these risks into account when making capital allocations. Taken in conjunction with the results from the previous paragraph, it seems that IFIs are managing their capital to address other risks, perhaps more frequent, less severe threats. Consistent with this result, surveying managers at several African IFIs, Castellani et al. (2009) find that while these IFIs are exposed to natural disasters, they do not actively manage these risks, explicitly reporting that they rely on the hope for external contingent aid to recapitalize if a disaster occurs.

The capital-to-asset ratio is significantly positively associated with financial expenses and negatively associated with being regulated, suggesting that market discipline but not public supervision motivates reserving. Regarding financial expenses, firms are motivated to choose a cost-minimizing financing structure (Modigliani and Miller, 1958). Thus, IFIs facing high debt financing costs tend to fund operations through equity. We interpret this result as the market recognizing high levels of risk for these IFIs, pricing it into debt investments, and so motivating IFIs to operate with high capital-to-asset ratios. Regarding the negative influence of regulation, we know of no regulation that explicitly encourages IFIs to hold lower capital-to-asset ratios; therefore, we believe this surprising result is due

to differences in regulated and unregulated IFIs for which the model does not account. IFIs operating in jurisdictions of higher regulatory quality do tend to hold higher capital-to-asset ratios, potentially suggesting that stronger regulating institutions impose more stringent standards.

Table 4.4: Determinants of capital-to-asset ratios

Mean model with logit link					
Coefficients	Estimate	Std.Error	z value	Pr(> z)	
(Intercept)	3.330	0.359	9.285	0.000	***
ln(Assets)	-0.195	0.021	-9.220	0.000	***
ROA	2.621	0.398	6.592	0.000	***
Financial Expenses/Assets	-16.098	1.093	-14.732	0.000	***
Loan Balance/GNI per Capita	-0.058	0.036	-1.606	0.108	
Provisions/Assets	0.470	1.181	0.398	0.691	
PAR>90	-0.084	0.556	-0.151	0.880	
Writeoff Ratio	2.168	0.658	3.293	0.001	***
Inflation	0.004	0.004	1.106	0.269	
Political Stability	0.063	0.068	0.921	0.357	
Government Effectiveness	-0.029	0.121	-0.244	0.807	
Disasters: Affected	-1.315	1.326	-0.991	0.321	
Disasters: Economic Damage	0.070	0.044	1.578	0.115	
Regulated (0=no,1=yes)	-0.207	0.091	-2.266	0.023	**
Regulatory Quality	0.247	0.117	2.114	0.035	**
Region (Reference: Latin Am. & Carr.)					
Africa	-0.044	0.126	-0.349	0.727	
East Asia and the Pacific	-0.134	0.128	-1.049	0.294	
Eastern Europe and Central & Asia	0.411	0.105	3.908	0.000	***
Middle East and North Africa	0.876	0.186	4.701	0.000	***
South Asia	0.155	0.202	0.769	0.441	
Legal Status (Reference: Nonbank FI)					
Bank	-0.240	0.116	-2.066	0.039	**
Credit Union / Cooperative	-0.401	0.108	-3.724	0.000	***
NGO	0.069	0.088	0.780	0.436	
Rural Bank	-0.256	0.214	-1.196	0.232	
Other	0.631	0.271	2.328	0.020	**
Phi coefficients (precision model)					
(Intercept)	-1.555	0.511	-3.041	0.002	***
ln(Assets)	0.227	0.031	7.343	0.000	***

Beta regression, dependent variable: capital-to-asset ratio

Type of estimator: maximum likelihood

Log-likelihood: 321.8 on 27 Df

Pseudo R-squared: 0.463

Number of iterations: 35 (BFGS) + 3 (Fisher scoring)

4.5. Inclusive finance and public and private supervision

Since markets are motivating IFI capital reserves, a logical consideration is whether public intervention is needed for this sector. In our view, yes, it is. The same rationale motivating international standards apply — that externalities in the banking sector affect the real economy, which the research on natural disasters described in Section 4.4 seems to corroborate.

While IFIs may not represent systemically important institutions to the global economy, their resilience influences the well-being of the economies of the communities and regions they serve.

The incentives of socially oriented investors such as development banks and microfinance investment intermediaries are, in principle, better aligned with the public's than would be purely private sector investors. Still, financial viability limits the social outreach of these investors. For example, several microfinance investment intermediaries have reported to us that they can manage systemic risks such as disasters through global diversification. This approach understandably protects their fund performance; however, it does nothing to address the hardships of the affected region, illustrating the limit of these investors' purview. While these fund managers hope to do good, their ultimate responsibility is to their shareholders, not the countries in which they invest. Recent microfinance bubbles in India, Nicaragua, Morocco, Bosnia and Herzegovina, and Pakistan, which developed in part due to the exuberance of social investors, illustrate the point and highlight the shortcomings of market discipline and the many social consequences of these crises (CGAP, 2010; Polgreen and Bajaj, 2010).

Thus, the need seems to exist for a public agent to represent the interests of the local credit market and its associated economy. Given its wide adoption, a logical consideration is whether the Basel Accords represent an effective framework for managing the systemic risks faced by IFIs. For example, because IFIs engage in high risk activities, perhaps the Basel Accords could be used but with more stringent requirements, e.g., 20% minimum capital requirements rather than 8%. In our view, no, the Accords are not an effective framework as they would be applied to IFIs. The wide adoption of the Basel Accords has led to the quite important outcome of wide recognition for the need for minimum capital holdings among FIs in developing and emerging economies; however, it is also riddled with problems. This section describes specific elements of the Accords, focusing on two limitations.

First, the Basel Accords are not sensitive to the risks faced by IFIs. Policy mechanisms (e.g., taxes, quotas, etc.) address externalities by aligning FI objectives with social welfare. In this case, the emphasis on the negative externalities of FI failure implies that FIs want to take on more risk than is socially optimal so effective policy mechanisms would increase the cost of risk-taking and/or reward risk reduction. Because the Accords are insensitive to the systemic risks of IFIs, they do not have the capacity to align the public and private rewards of risk taking.

Second, the Basel Accords do not offer flexibility in managing risk for IFIs. Public intervention to address market failures comes at an opportunity cost. Similar to financing an FI, financing systemic risk management can often be done using a blend of mechanisms. Allowing for an effective blend can lower the cost of managing the risk, creating a Pareto improvement over more restrictive approaches. Because the Accords do not offer flexibility in managing systemic risk to IFIs, they unnecessarily increase its social cost.

4.5.1. Flexibility in systemic risk management

Mechanisms and strategies to manage systemic risks fit into three broad categories: diversification, risk transfer (e.g., insurance and debt instruments), and reserving; the Basel Accords motivate IFIs in developing and emerging economies to rely exclusively on capital reserves to manage systemic risks. Minimum capital requirements (reserves) tend to be the most generalizable strategy as they create protection against any source of loss. Two simplifying assumptions underlie the risk measurement and capital requirements of the Accords: 1) borrowers are exposed to a single systemic risk factor; and 2) the portfolio is asymptotically fine-grained so that the FI is not exposed to the undiversified risks of borrowers — that is, the Law of Large Numbers is not undermined by portfolio concentrations (Blundell-Wignall et al., 2010; Gordy, 2003; Tirole, 1994). In principle, these conditions could hold for large, global banks. Those banks theoretically would be able to manage all systemic risks through diversifications except a global business cycle, which would be managed via minimum capital requirements (Gordy, 2003). IFIs do not meet the basic theoretical assumptions underlying this approach. Empirical evidence, including research published by the Basel Committee, shows that many of these FIs are exposed to a variety of localized risks and manage portfolios with large concentrations but are only limitedly exposed to global business cycles (BCBS, 2010; Griffith-Jones et al., 2003).

These simplifying assumptions reduce the assessment burden on supervisors and IFIs, but come at a substantial private and public cost. First, they assume away a need to encouraging diversification, the cornerstone of portfolio risk management (Markowitz, 1952). Second, while capital reserves are effective for protection against relatively small systemic events, reliance on capital reserves to manage large shocks tends to contribute to cyclical credit provision, as described in Section 4.3.3. Large systemic events that destroy FI capital motivate FIs to contract credit to realign their capital ratios to target levels

(Collier, 2013). Moreover, for capitally constrained IFIs, reliance on capital reserves limits the size of an IFI.

Based on shortcomings of Basel I, both Basel II and III offer increased flexibility for FIs to use their internal models to assess and manage risk. For example, FIs using these more advanced approaches can manage a portion of operational risks using insurance. Unfortunately, the technical requirements for these more advanced methods preclude their use among almost all developing country FIs (BCBS, 2010). As a telling anecdote, Peru has adopted regulations closely aligned with Basel II and III. In 2012, the Peruvian regulator told us that *no* Peruvian FI had the capacity to use the sophisticated methodologies in the Accords. Peru has a large banking sector, strong regulator, and sophisticated FIs. Instead, IFIs operating under Basel II use the “Standardized Approach” for managing credit risk. The Standardized Approach is roughly equivalent to the methodologies used in the 1980s under Basel I, offering crude rules for assessing risk and very little flexibility in managing it.

4.5.2. Risk sensitivity

Capital requirements in the Basel Accords are for *risk weighted* assets. Risk weights are derived from the recognition that asset holdings differ in their level of risk and so require different levels of reserving. A risk weight acts as a scaling factor on the value of the risky asset in determining capital requirements. A wealth of literature exists on risk weights because Basel I relied on this approach (e.g., Repullo and Suarez, 2004; Rochet, 2005; Santos, 2001). To summarize, properly calibrated risk weights are theoretically plausible but very challenging to implement. Based on the negative externalities assumption, FIs want to take on more risk than is socially optimal so they are motivated to circumvent regulation that limits their risk taking. When risk weights are insensitive to differences across assets, opportunities for capital arbitrage emerge (Kim and Santomero, 1988; Rochet, 1992). Evaluating the performance of Basel I from 1988 to 1996, a report from the Basel Committee (1999) concludes that through capital arbitrage via *cherry picking* (i.e., choosing the riskiest borrowers in a risk category) and holding risk off-balance-sheet, FIs were subverting capital requirements in a way that made them limitedly meaningful.

The risk weights applied to IFIs under the Standardized Approach are insensitive to the risks of FI borrowers. The loan categories are amazingly broad as loans across almost all economic sectors fall in the same category. For example, loans to individuals or small

businesses carry a risk weighting of 75% and loans to corporations carry risk weights of 100%. Thus, the Standardized Approach suggests that a loan to a farmer in Ghana, a fisher in Guatemala, and a florist in Germany all carry the same systemic risk exposure.

Similarly, investors and credit rating agencies can also fall in the trap of taking risk criteria for developed countries and applying them to IFIs in developing and emerging economies. For example, we highlight our experiences with two internationally active institutions, a large, socially oriented investment fund manager and a credit rating agency for IFIs in northern Peru, which is exposed to severe flooding from El Niño. Each acknowledged that these IFIs are highly vulnerable to severe El Niño events, but each also reported that this vulnerability does not affect their evaluation because natural disaster risk did not fit neatly into their evaluation protocols.

4.5.3. Implications of the Basel Accords for IFIs

Given the limitations of the Basel Accords for IFIs, we explore theoretical implications of their use in this sector. This section models the informational challenges facing IFIs and their tendency to lead to portfolio concentrations and the effect of the Basel Accords.

Consider a representative IFI that is contemplating expanding the geographical scope of its operations. The IFI currently operates in a region exposed to a single systemic risk ψ . The IFI can originate new loans in its current region l_ψ and/or lend to the same type of borrowers in a neighboring region l_χ , which faces a different systemic risk χ .³ The IFI faces information costs $C(l_\chi)$ in expanding to the new region associated with acquiring and monitoring new clients, infrastructure investments, etc. These costs increase at an increasing rate ($C' > 0, C'' > 0$). For example, the IFI can monitor borrowers in the new region operating near its current branches by mobilizing its field officers; however, to monitor more of the new region, the IFI would need to open branches there.

The IFI is a price-taking firm that maximizes a quadratic mean-variance utility, offering single-period loans. The IFI solves

$$\max_{l_\psi \geq 0, l_\chi \geq 0} \mu - \frac{\lambda}{2} \Sigma \quad (4.1)$$

where $\mu = E[R_\psi]l_\psi + E[R_\chi]l_\chi - r(l_\psi + l_\chi - K) - C(l_\chi),$

$$\Sigma = l_\psi^2 \sigma_\psi^2 + l_\chi^2 \sigma_\chi^2 + 2l_\psi l_\chi \sigma_{\psi\chi},$$

³For ease of exposition, we assume that systemic risks ψ and χ are normally distributed.

λ is a measure of the magnitude of risk aversion, R_i is the return on loans exposed to systemic risk i , $R_i \geq -1$, r is the interest rate paid on IFI liabilities, K is the level of equity held by the IFI, and $\sigma_\psi^2, \sigma_\chi^2$, and $\sigma_{\psi\chi}$ are the respective variances and covariances of returns on loans exposed to the systemic risks ψ and χ . For simplicity, we assume the expected returns in each region are the same ($E[R_\chi] = E[R_\psi]$) and some lending will occur in both regions. Solving this maximization yields

$$C'(l_\chi) = \lambda(l_\psi\sigma_\psi^2 - l_\chi\sigma_\chi^2 + (l_\chi - l_\psi)\sigma_{\psi\chi}). \quad (4.2)$$

The IFI equates the portfolio benefits of lending in the new region to the marginal cost of information. In this way, the cost of information motivates IFIs to increase regional and economic sector concentrations.

Given this foundation, we impose the Basel Accords on this IFI. As Section 4.4 illustrates, markets tend to recognize more risk for IFIs than is addressed with an 8% minimum capital requirement. Therefore, we assume the regulator, using the Accords as a framework, imposes more stringent minimum capital requirements. For example, IFIs in Peru have traditionally faced a minimum requirement of 14%.

With an imposed minimum capital requirement of δ , the IFI's problem is

$$\begin{aligned} \max_{l_\psi \geq 0, l_\chi \geq 0} \quad & \mu - \frac{\lambda}{2}\Sigma \\ \text{s.t.} \quad & \frac{K}{\boldsymbol{\omega}^T \mathbf{L}} \geq \delta \end{aligned} \quad (4.3)$$

where $\boldsymbol{\omega}$ and \mathbf{L} represent n by 1 vectors of risk weights and loan values held in different risk classes, respectively. Because negative externalities motivate IFIs to take on more risk than regulators like if regulations were calibrated effectively, we treat the constraint as binding. We can write this equation as a Lagrangian

$$\mathcal{L} = \mu - \frac{\lambda}{2}\Sigma + \gamma \left(\frac{K}{\boldsymbol{\omega}^T \mathbf{L}} - \delta \right). \quad (4.4)$$

Proposition 1: The Basel requirements do not affect geographic concentrations or concentrations among loans with the same risk weight. First, we consider how the requirements outlined in the Basel Accords might affect the concentration of risk in the portfolio associated with borrowers of a similar type. As a reminder, categories are

very broad under the Standardized Approach; all loans to individuals and small businesses receive the same risk weight. Thus, all of the borrowers for some IFIs will fall into the same loan type. The modeled IFI lends to small enterprises in both regions, which receive a risk weight of ω_s . Including the capital requirement and continuing to hold the simplifying assumption that the expected returns across regions are equal, we re-derive the first order conditions and use a substitution to yield

$$C'(l_\chi) - \gamma \frac{K}{(\omega^T \mathbf{L})^2} \omega_s = \lambda(l_\psi \sigma_\psi^2 - l_\chi \sigma_\chi^2 + (l_\chi - l_\psi) \sigma_{\psi\chi}) - \gamma \frac{K}{(\omega^T \mathbf{L})^2} \omega_s. \quad (4.5)$$

Because loans in each region are made to borrowers with the same risk weight and capital requirements are calculated at the portfolio level, the imposed capital requirement affects each region equally and thus fall out of the equation. This yields

$$C'(l_\chi) = \lambda(l_\psi \sigma_\psi^2 - l_\chi \sigma_\chi^2 + (l_\chi - l_\psi) \sigma_{\psi\chi}) \quad (4.6)$$

which reproduces the portfolio allocation from Equation (4.2), before the capital requirement was introduced. Thus, these capital requirements do not affect portfolio allocation across geographic regions or borrowers in the same loan category. The IFI continues to build a portfolio concentration in the region exposed to risk ψ to avoid the cost of expanding to the new region.

Proposition 2: The Basel requirements can create deadweight losses by reallocating credit where risk weights are “cheapest.” Differing risk weights can change loan allocations *across* loan categories even though the risk weights in the Basel Accords are unaffected by changes in the systemic risks faced by developing country IFIs (e.g., $\frac{\partial \omega_s}{\partial \sigma_\psi} = 0$). As an example, we consider an IFI that holds two classes of assets — say, loans to corporations l_c and loans to small enterprises l_s . Before risk weights are imposed, the optimal loan allocation across asset classes results in

$$E[R_s] - E[R_c] = \lambda(l_s \sigma_s^2 - l_c \sigma_c^2 + (l_c - l_s) \sigma_{cs}). \quad (4.7)$$

Rather than lending exclusively to borrower class that provides the highest expected return, the IFI balances the spread in expected returns with the risk reduction benefits of diversifying across loan types. Now, we include the Basel-style risk weights, leading to a first order condition of

$$E[R_s] - E[R_c] = \lambda(l_s\sigma_s^2 - l_c\sigma_c^2 + (l_c - l_s)\sigma_{cs}) - \gamma \frac{K}{(\boldsymbol{\omega}^T \mathbf{L})^2} (\omega_c - \omega_s) \quad (4.8)$$

where ω_c and ω_s are the risk weights for corporate and small enterprise loans respectively. The risk weights migrate capital away from efficient market allocations toward loans where the capital charges are lowest relative to the risk. This reallocation is associated with a deadweight loss in social welfare and a cross-subsidization of credit from loan categories with “expensive” risk weights to those with “cheap” ones. Given that the credit markets in many developing and emerging economies are underdeveloped, this deadweight loss and arbitrary reallocation are troubling.

Proposition 3: The Basel requirements limit access to credit. Capital requirements limit the supply of credit. We have modeled the capital requirement as an optimization constraint and shadow price interpretations of the Lagrange multiplier γ apply. This cost of the supply constraint is passed on to borrowers via the lending interest rate. We continue with our example of the representative IFI that only lends to corporations and small enterprises. We can derive the competitive interest rate charged by this representative IFI via its first order condition with respect to small enterprise loans

$$R_s = r + \lambda(l_s\sigma_s^2 + l_c\sigma_{cs}) + \gamma \frac{K}{(\boldsymbol{\omega}^T \mathbf{L})^2} \omega_s. \quad (4.9)$$

In this equation, r represents the cost of funds for the IFI which is passed on to borrowers, $(l_s\sigma_s^2 + l_c\sigma_{cs})$ represents the incurred risk from making the loan for the IFI, λ is its risk premium rate, and $\gamma \frac{K}{(\boldsymbol{\omega}^T \mathbf{L})^2} \omega_s$ represents a type of tax on borrowers due to the scarcity of IFI capital associated with the capital regulation. In this framework, increases in the capital requirement δ result in higher interest rates ($\frac{\partial R_s}{\partial \gamma} \frac{\partial \gamma}{\partial \delta} > 0$). Given a declining demand function for credit, such as

$$R_s = \eta - \theta l_s \quad (4.10)$$

where η and θ are parameters, increases in the capital requirement also translate into lower equilibrium quantities of credit ($\frac{\partial l}{\partial \beta} < 0$). As empirical support, the Basel Committee, evaluating data from 1988 to 1996, finds some evidence in developed countries that increases in capital requirements associated with Basel I limited access to credit and reduced growth in certain economic sectors (BCBS, 1999).

4.6. Alternatives to the status quo and recommendations

The limitations of the Basel Accords can represent a quandary for developing country policymakers as they consider adopting new versions of the Accords. While the Basel Committee (2011a) notes that the standards adopted by any jurisdiction are the responsibility of its policymakers, Simmons (2001) describes the adoption of the Accords as a paradigm in which developing and emerging economies benefit from cooperating with a dominant power in financial markets, a coalition between the U.S. and Great Britain. Adoption communicates positive characteristics about the developing country jurisdiction and so may increase international investment (Simmons, 2001), protects the overseas operations of domestic FIs (Chey, 2007), and facilitates membership in multilateral organizations such as the World Trade Organization (Bismuth, 2010).

For regulators interested in tailoring prudential standards to better meet the needs of their jurisdictions, collective action is likely to increase the acceptance of the global community of deviating from international standards. For example, regulators could coordinate regionally to develop alternative prudential standards as neighboring jurisdictions are often at similar stages of development and vulnerable to the same risks. Because IFIs typically maintain high capital ratios due to risk, the cost of adopting the minimum capital requirements of Basel I and II may be relatively low. Regulators seemingly have plenty of room to innovate, using the Basel Accords as a foundation on which to build a broader set of risk management mechanisms. Adherence to Basel III may come at a higher cost as it imposes a number of additional standards in response to the problems faced by large banks during the 2008 Financial Crisis such as liquidity requirements, a maximum leverage ratio, and countercyclical capital buffers.

Coordination to increase IFI resilience also seems in the interest of inclusive finance investors due to both its social benefits and the new investment opportunities it would create. Because international investment in inclusive finance is concentrated in a handful

of development banks and investment funds in influential jurisdictions in Western Europe and North America, these investors are well positioned to influence public and private prudential standards. First, these institutions can coordinate at relatively low cost to enhance their investment practices. Progress has already been made through the United Nation's Principles for Investors in Inclusive Finance. The terms of these principles are quite general, but the endeavor signals the potential for additional collaboration in this sector. Second, these institutions can advocate on behalf of developing countries to change expectations regarding the adoption of international public prudential standards. The G20's recent emphasis on financial inclusion and the material on inclusive finance developed by the Basel Committee 2010 are favorable indicators that this advocacy may have already effectively begun.

4.6.1. Enhancing risk estimates

While creating risk-based requirements may be challenging, almost any sensitivity to risk would seem to improve on an arbitrary, fixed level of reserving irrespective of the risk, the status quo. Substantial scholarship exists on risk measurements in banking. Proposals for measurement and monitoring range from sophisticated academic pursuits (e.g., Andersen et al., 2004; Lucas et al., 2003; Szegö, 2002) to pragmatic approaches that are less rigorous but do improve on current standards at seemingly low transaction costs (e.g., Fernandez de Lis and Garcia-Herrero, 2010; Terrier et al., 2011). For example in Peru, FIs are required to hold additional capital above the standard regulated minimum based on 1) their importance to the financial system, 2) macroeconomic business cycles, 3) interest rate risks, and 4) geographic and economic sector concentrations (Superintendencia de Banca, Seguros, y AFP, 2011). Also, Uruguay imposes prudential standards to manage credit risk associated with foreign exchange fluctuations such as greater capital requirements for unhedged foreign currency loans and more stringent loan loss provisioning for all foreign currency loans (Terrier et al., 2011).

While proposing specific risk measures is beyond the scope of this paper, we do want to state our preference for simplicity. Complex methodologies often rely on simplifying assumptions to make them tractable; however, in real-world applications these assumptions can be egregiously violated. For example, Szegö (2002) describes the many limitations of value-at-risk, a risk assessment approach used in Basel II, noting that it fails to meet even the most basic requirements of a risk measure except under very restrictive assumptions.

Complexity can create blind spots in risk measures when models are beyond the technical capacity of many members in the sector. Between the insensitive standards passed down from Basel I and the highly technical ones added to Basel II and III lies a wide range of options that increase risk sensitivity without creating an undue burden on IFIs.

4.6.2. Increasing flexibility in risk management

Capital reserves are a flexible mechanism that can address FI losses from a variety of risks and thus deserve to be an important component of risk management mechanism for all FIs, especially for managing small systemic shocks. More comprehensive risk management strategies that also rely on diversification and risk transfer likely lower the cost and increase the effectiveness of risk management. Risk transfer is particularly well-suited to address infrequent, severe systemic shocks of specific concern. Both of these mechanisms reduce portfolio risk and so have the added benefit of reducing volatility in access to credit.

Diversification. Offsetting the cost of diversification through prudential requirements can align IFI interests with those of the public. For example, returning to the model in Section 4.5.3, suppose the regulator allows the representative IFI to meet prudential standards using a combination of capital reserves and diversification. Without diversification, minimum capital requirements are δ , but risk reduction through diversification lowers the capital requirement by $F(\Sigma)$, which is a function of portfolio risk Σ . The socially optimal policy would equate the marginal regulatory benefit to the IFI of diversification ($\partial F/\partial l_\chi \gamma$) to the marginal cost of information required to diversify ($\partial C/\partial l_\chi$). Adding this regulatory structure to Equation (4.5) yields

$$l_\chi \sigma_\chi^2 - l_\chi \sigma_{\chi\psi} = l_\psi \sigma_\psi^2 - l_\psi \sigma_{\chi\psi}. \quad (4.11)$$

The IFI chooses the risk minimizing portfolio.

As already mentioned, Peru is implementing an approach in this spirit. Traditionally, the regulator has maintained a 14% minimum capital requirement for IFIs; however, it is moving to a system of a minimum capital requirement of 10% and four percentage points of potential additional capital requirements based on risk. An IFI that minimizes its geographic and economic sector portfolio concentrations via diversification has the potential to lower its minimum capital requirement by up to two percentage points (Superintendencia de Banca,

Seguros, y AFP, 2011). This change would allow an IFI to increase its loan allocations by about 12%.

Risk transfer. Risk transfer is a specific form of asset diversification in that the returns of risk transfer products such as insurance are negatively related to other assets in the portfolio. Systemic risks such as natural disasters are best addressed by transferring them internationally where counterparties have the capacity to diversify globally. Portfolio guarantees and similar instruments make payments based on portfolio-level loan losses. These mechanisms can create moral hazard for IFIs so finding counterparties, especially internationally, at risk transfer rates acceptable to IFIs may be quite challenging.

Disaster-based mechanisms such as index insurance may be particularly valuable for managing natural disaster risks.⁴ Index insurance is designed on an objective measure of the natural disaster of concern. For example, a measure insuring against hurricane risk could make payouts based on sustained windspeed and rainfall. Index insurance has several benefits over traditional insurance including 1) reduced moral hazard and adverse selection, which reduces the cost of the insurance, and 2) quicker payouts as they are made based on the objective index Barnett and Mahul (2007). This timely insurance payout comes as a sum of cash to the FI that could both address immediate liquidity needs and offset capital losses due to loan write downs, putting IFIs in a stronger position to operate after a severe event. Index insurance against severe El Niño is now being used by an IFI to protect its portfolio as it expands lending in northern Peru (Collier and Skees, 2012). The primary weakness of index insurance is basis risk — the risk of a mismatch between the severity of the natural disaster and losses. A comprehensive risk management strategy that uses several risk mechanisms reduces the consequences of basis risk

In the long-term, debt and insurance-like hybrid instruments may be particularly useful for addressing medium to large systemic shocks. For example, contingent capital is a debt instrument that transforms into capital based on a certain event (Hanson et al., 2010). So far contingent capital has been issued by large, publicly traded FIs (e.g., UBS, Credit Suisse, Lloyd’s Banking Group, Rozanksy, 2011). Contingent capital mechanisms would make the counterparty an owner in the FI when its capital ratio is low, when the FI is most at risk. These mechanisms seem most likely to emerge following the development of other risk transfer mechanisms for IFIs.

⁴Index insurance is a specific example of a class of parametric risk transfer mechanisms which can be structured in several ways including as derivatives.

Illustrating the benefits of risk transfer

Risk transfer can increase the loss capacity of IFIs and so the amount they can lend. We illustrate these benefits and important limitations using the following model. Suppose a representative IFI holds a certain amount of equity capital \bar{K} , and as part of its risk evaluation, the IFI considers the size of loss it can sustain without becoming insolvent. While the amount of equity is fixed, we assume the IFI can take on as much debt as it would like via deposits and interbank loans. The IFI has a large exposure to systemic risk ϕ which we will call *cyclone risk* and an exposure to a variety of other systemic risks to which it is either limitedly vulnerable or the risk is remotely probable (e.g., global business cycle, political regime change, alien invasion, etc.), which we denote using the vector \mathbf{v} . The realization of one of these systemic risks causes some portion $z_t(\phi, \mathbf{v})$ of the value of the loan portfolio to be lost.

First, we consider a scenario where the IFI incurs losses due to a cyclone and the only mechanism available to the IFI to manage the event is capital reserves. The IFI remains solvent up to the point where its assets equal its liabilities, i.e., equity is zero. Equity evolves according to the process

$$K_{t+1} = K_t + RL_t - rD_t - z_t(1 + R)L_t \quad (4.12)$$

where R is the lending interest rate, r is the interest rate on IFI liabilities, and K_t , L_t , and D_t are IFI equity, loans, and liabilities in period t , respectively. IFI losses are generated from revenue and asset losses $z_t(1 + R)L_t$. By setting $K_{t+1} = 0$ and using the IFI's budget constraint $L_t = D_t + \bar{K}$, we can derive magnitude of loss that the IFI can incur and remain solvent

$$z_1^* = \frac{1}{1 + R} \left(\frac{(1 + r)\bar{K}}{L_t} + R - r \right). \quad (4.13)$$

The capacity of the IFI to manage losses is limited to its starting capital and returns from lending. Equations (4.13) can be rewritten to identify the loan portfolio that this loss management capacity can support

$$L_t^* = \frac{(1 + r)\bar{K}}{z_1^* - (R - r)}. \quad (4.14)$$

In other words, if the IFI maintains a capital ratio of at least \bar{K}/L_t^* , it will remain solvent in the event of z_1^* losses.

Second, we consider the capacity of the IFI to manage losses using capital reserves and insurance against cyclone risk. The insurance payout takes the form $I_t(z_t(\phi))$ where $z_t(\phi)$ denotes losses due to cyclones. This insurance can be purchased at the premium rate p so that the total premium is pI_t . The cost of the insurance enters the IFI's equity transition function (4.12) and the expenditure enters the budget constraint as funds that could have been used for lending go toward the insurance $L_t + pI_t(z_t) = D_t + \bar{K}$. Theoretically, the IFI could fully transfer its risk through the insurance so that it would not require any capital reserves. If so, the loan portfolio could be infinitely large; however, given that the IFI is exposed to a variety of systemic risks, the regulator determines that only a portion β of its loan losses can be managed using insurance.⁵ Following (4.13), we can derive the capacity of the IFI to manage losses using capital reserves and insurance

$$z_2^* = z_1^* + \frac{(1 - p(1 + r))\beta I_t}{(1 + R)L_t}. \quad (4.15)$$

Because $p(1 + r) < 1$ for any case where the IFI chooses to buy insurance, the second term on the right hand side is positive. Thus, a risk management strategy of blending capital reserves and insurance increases the capacity of the IFI to manage losses and so increases the size of the loan portfolio that this IFI can maintain, increasing local access to credit.

As a third scenario, we consider the case where the IFI insures against its cyclone risk but an uninsured systemic event such as political regime change occurs. The loss capacity in this scenario is

$$z_3^* = z_1^* - \frac{p(1 + r)\beta I_t}{(1 + R)L_t} \quad (4.16)$$

which is the lowest across the three examples. This result illustrates a more general principle that insuring against a specific systemic risk reduces the capacity of an FI to manage other risks.⁶ Insurance is best used for low probability, high severity systemic risks, and the proportion of losses that can be managed with risk transfer (β) should be set based on the relative importance of the insured risk to the other risks faced by the IFI.

Because index insurance makes payments based on a measure of the risk event, modelling its benefits requires another step. To capture basis risk, we assume an imperfect relationship between the systemic risk and IFI losses $z_t = g_t(\phi) + \epsilon_t$ where ϵ_t is an error term. While basis risk creates greater uncertainty about the relationship between insurance payouts and

⁵An insurer offering loss-based risk transfer would also prefer for the IFI to manage some of its risk via reserves as a form of deductible that reduces moral hazard.

⁶Miranda and Gonzalez-Vega (2011) find a similar result for borrowers.

losses, it is worth noting that determining the capital reserves required to manage a systemic risk also requires mapping the risk to IFI losses, which will include some error. In sum, risk transfer can benefit IFIs, especially when attracting equity capital is difficult and/or costly, but should be implemented carefully when IFIs have large exposures to a variety of systemic risks.

4.7. Conclusion

The many and growing resources devoted to increasing financial inclusion are encouraging as the collective actions of bankers, policymakers, and investors can benefit the many who have been excluded from financial markets. Systemic risk remains a significant constraint in access to financial services that is largely overlooked by the banking community that sets priorities for risk management. Interjurisdictional coordination among policymakers and among market decision makers is needed and some progress is already emerging. The recommendations presented here have the potential to increase the outreach and resilience of inclusive finance.

Chapter 5. Conclusion

This dissertation is part of my broader research program regarding the effects of natural disasters on development-oriented investment in developing and emerging economies. Specifically, this dissertation explores the implications of natural disaster risk for access to financial services, especially credit. It demonstrates that not only does disaster risk reduce the provision of credit, but that the economic consequences of these events are magnified because disasters tend to reduce the credit supply after an event. Systemic risk management relies on the priorities of regulating supervisors and investors, making these decision makers instrumental in determining whether and how disaster-related credit risk is managed. Assessment and monitoring of disaster risk has been overlooked by the financial environments of many developing and emerging economies due to their adoption of developed country risk management approaches; however, this dissertation demonstrates that public and private interest align in tailoring disaster risk standards in vulnerable economies. Financial mechanisms such as insurance show promise in reducing the consequences of natural disasters and may be most effective when designed for use by financial intermediaries (FIs) rather than households.

The dissertation is organized around four objectives. Objective 1 entails identifying challenges that natural disasters create for FIs. This objective is motivated by evidence that, despite its rapid growth, inclusive finance is not reaching disaster-vulnerable markets such as agriculture (Consultative Group to Assist the Poor, CGAP, 2011a). Chapter 2 in the dissertation models a representative, dynamically optimizing lender managing a stock of equity capital in order to maximize divided payments to its shareholders. The model is calibrated using data from a Peruvian FI specializing in microfinance and vulnerable to the risk of severe El Niño, an event that brings torrential rains and flooding in northern Peru. It demonstrates that loan losses from the event destroy the capital of the lender. Following the disaster, the lender reduces its loan allocations, bringing them in line with its smaller capital base but also limiting access to credit for borrowing households and firms. The risk

of this event leads FIs to make fewer loans with a given capital base, reducing the total provision of credit. This paper helps explain macroeconomic evidence that credit market development significantly influences the total economic cost of a disaster. Especially in regions where credit markets are underdeveloped, FIs are unlikely to be able to meet the increased demand for credit needed for reinvestment after a severe event, increasing the economic cost of the disaster.

Given the economic and developmental implications of disasters for developing and emerging economies, the dissertation pursues a second objective: evaluate the potential of insurance to reduce disaster-related disruptions in credit provision. Chapter 2 pursues this objective by introducing an insurance-like mechanism to be purchased by FIs for the purpose of transferring their disaster risk. The results show that insurance stabilizes lender income and dividend payments and avoids credit contraction. Moreover, because insurance reduces its risk, the FI is motivated and better able to operate closer to its minimum capital requirement, more fully leveraging its capital. Thus, this research indicates that insurance improves the risk profile of the FI by reducing volatility in its earnings and allowing for more consistent dividend payments. Additionally, the insurance provides social benefits by increasing access to credit under non-disaster conditions and reducing credit contractions when natural disasters occur.

Insurance could contribute in a variety of ways to increase the resilience of vulnerable communities. As a result, the dissertation pursues a third objective of evaluating potential developmental tradeoffs in managing disaster-related credit risk using products designed to be purchased by FIs versus those designed for borrowing households. Index insurance is the primary insurance mechanism used to address disaster risk in recent development projects. Index insurance makes payments based on an objective measure of a disaster (e.g., insuring against drought using rainfall at the closest weather station), rather than assessing the losses incurred by the insured.

Chapter 3 demonstrates two important limitations regarding index insurance for households. First, household products tend to have higher basis risk than products for FIs. Basis risk describes the possibility that the measurement of the disaster used to make insurance payments will differ from that experienced by the insured. Higher basis risks limits the efficacy of household products because households remain exposed to the risk of large disaster losses. Second, because only a portion of vulnerable households default when a disaster occurs, using household insurance tends to over-insure the credit risk, effectively increasing

the cost of credit. While households may have many uses for insurance against a specific natural disaster, this research suggests that for the specific application of managing credit risk, insurance for FIs is a more effective and efficient mechanism.

Objective 4 evaluates the incentives of FIs to manage natural disaster risk in socially desirable ways. Chapter 4 pursues this objective. It documents the rapid growth of investments in inclusive finance in developing and emerging economies where disaster vulnerability is high. Many inclusive finance intermediaries (IFIs) are supervised using the Basel Accords, international banking standards designed for large banks in developed countries. Those standards are relatively insensitive to the risks faced by IFIs. They also rely on minimum capital requirements for managing systemic risks. These requirements were specifically designed to protect against global business cycles and are intended to guard the solvency of FIs during such a crisis, reducing shocks to credit markets. Supervisor or investor interventions associated with violating minimum capital requirements are onerous to FIs, leading to a stalemate — FIs hold more reserves than they would otherwise, but when shocks occur FIs tend to focus on managing minimum capital requirements (Ediz et al., 1998; Rime, 2001), exacerbating credit contraction as demonstrated in Chapter 2.

Supervisors and investors have the opportunity to recognize a broader range of mechanisms to manage particularly worrisome systemic risks, such as disaster risks for some FIs. A variety of approaches can assist FIs in managing disaster risk. Using a combination of complementary mechanisms and approaches likely lowers risk management costs and increases its effectiveness. Each risk management mechanism comes at an opportunity cost and so is best used with respect to its comparative advantage. For example, diversification reduces portfolio concentrations, but comes at the cost of developing lending expertise in new regions and economic sectors. Likewise, insurance and other risk transfer mechanisms have attractive qualities, but resources devoted to insuring one specific risk cannot be used to manage other systemic risks. Because international standards focus so heavily on minimum capital requirements, FIs who could be using a variety of mechanisms to manage systemic risk may instead use them to manage capital reserves. Chapter 2 demonstrates that under this paradigm, the optimal use of insurance is not to manage shareholder losses or smooth the provision of credit, but to stabilize the capital ratio to avoid intervention from supervisors and investors. Formal recognition of a broader set of systemic risk management mechanisms could better align the incentives of FIs with public and private interests.

5.1. Implications for development intervention

The dissertation has important implications for development-oriented investments and interventions. First, it challenges the notion that increasing the volume of international investment in inclusive finance will naturally progress to developed financial markets serving the poor in vulnerable regions and sectors. Industry reports on inclusive finance investment note that despite massive growth in recent years, cross-border funding continues to avoid high-risk markets, choosing instead to invest in a handful of very large FIs (MicroRate, 2012). The dissertation offers a partial explanation for this result by demonstrating the limited capacity of FIs to manage even mild systemic losses from disasters. Rather than more cheap financial capital, which has the potential to create credit bubbles and crowd out the private sector by continuing to fund the biggest institutions, the dissertation suggests that the introduction of risk management mechanisms such as insurance is likely necessary to increase financial inclusion in certain regions and sectors.

Second, while insurance can increase access to credit for those vulnerable to natural disasters, development projects focused on household-level insurance markets may unnecessarily increase the cost of disaster risk management by design. Rather than relying on household products that tend to over-insure disaster-related credit risk and operate with higher basis risk, development practitioners may have a greater chance of reaching their socially-oriented objectives by employing insurance designed for FIs. While more experimentation in the field is needed, products for FIs seem likely to lower the cost of providing credit to vulnerable markets, more effectively manage systemic risk, and have a greater potential for scale, benefiting more households.

Third, projects that fail to include regulating supervisors and investors face unnecessary risk. Assessing and meeting customer demand remains a consistent theme across development-oriented insurance projects, and disaster insurance for FIs is no different. While this research identifies a great need for disaster-related insurance products designed for FIs, it also suggests that the uptake and use of these products will be significantly influenced by the willingness of regulating supervisors, investors, and credit rating agencies to recognize their benefits. Thus, demand considerations for lender-level disaster insurance extend beyond decision makers in an FI to the many, diverse stakeholders in a financial system. While insurers may be willing to cooperate with donors funding the development of new product lines for them, their ability to sell insurance against natural disasters to

FIs may be undermined if the financial environment does not value managing disaster risk. Development practitioners rarely include regulating supervisors and investors in assessing vulnerability and designing appropriate financial mechanisms (Murphy et al., 2011), but their participation seems likely to enhance a project’s relevance and increase the potential viability of the financial mechanisms it develops.

5.2. Limitations and extensions

This dissertation is a starting point for research on this topic and has a number of limitations. This section reviews some limitations and points toward research extension that I would like to pursue. First, the models in the dissertation evaluate disaster risk in isolation of other systemic risks such as business cycles, currency fluctuations, commodity price shocks, etc. The variety of risks facing FIs motivate comprehensive risk management strategies that include layering financial mechanisms. Capital reserves are ubiquitous, flexible, important mechanism for managing small systemic shocks. For the risks of greatest existential concern to the FI, insurance represents an attractive alternative. The model in Chapter 2 is most relevant for FIs worried about a specific natural disaster risk; for FIs exposed to many large systemic risks, its results overstate the benefits of insuring. New mechanisms such as contingent capital — debt instruments that become equity under adverse conditions — will tend to be unavailable for IFIs. In the long-term, these mechanisms may represent an intermediate step, a risk management tool for medium to large losses, that has greater flexibility than insurance, but likely comes at a higher cost for managing tail risks. In sum, one limitation of this dissertation is its treatment of disaster risk as an isolated systemic risk, and extensions of disaster modeling into the world of multivariate risks experienced by many FIs would seem to be a needed and potentially fruitful area of research.

Second, additional empirical evidence is needed illustrating the effects of disasters on credit supply. The dissertation provides a result unanticipated in its development, namely that disasters only constrain the provision of credit when FIs are operating in the vicinity of their minimum capital requirements. Because nascent market conditions led FIs in northern Peru to operate with large capital reserves in the period leading up to severe El Niño, modeling in this dissertation provides important information about current vulnerability, but is inappropriate for empirical validation using the 1998 event. Discussions with professionals in the financial sector indicate that the capital dynamics illustrated in the dis-

sertation are consistent with their experience; however, verification via empirical examples would strengthen the results of this dissertation and is an area of future research I plan to pursue.

Third, relatively little is known about the determinants of disaster-related credit risk. At the household and small firm level, FIs are collecting more data on their borrowers and so analyses of borrower characteristics and their influence on disaster-related credit risk are possible and quite important for assessing, managing, and pricing disaster risk in loans. Similarly, disaster risk seems to influence access to international investment for FIs. A clearer understanding of disaster-related credit risk at the FI level is needed to strengthen and expand investment channels. While obtaining access to these data may be challenging, I intend to pursue this research.

Finally, many questions regarding the effects of disasters on credit market equilibrium remain. First, demand for credit after an event will tend to increase due to reinvestment needs. This dissertation is limited in that it did not model these demand-side issues and their implications. Lender supply shocks as modeled in Chapter 2 would increase the cost of recovery for affected households and firms. Theoretical and empirical research are needed to study these dynamics. Second, there is some risk that disaster losses may have system-level consequences, negatively affecting non-vulnerable sectors through credit channels. Capital reserves are managed across all of the operations of an FI; therefore, large losses in one sector can create a credit contraction for many sectors. Additionally, while FIs may not be lending directly to vulnerable markets, they may be lending to FIs that are. Strong interdependencies in financial systems are common, but it is unclear whether severe disasters have been an important source of contagion that propagates through a financial system. Research on this topic is of high value and particularly relevant for setting public policy priorities and one of my long-term research goals.

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Curriculum Vita

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Education

Ph.D.	Agricultural Economics, University of Kentucky	2013 (in progress)
M.S.	Economics, University of Kentucky	2010
M.S.	Psychology, University of Kentucky	2006
B.A.	Psychology, Asbury University	2003

Professional Positions

Wharton Risk Management and Decision Processes Center, University of Pennsylvania	Postdoctoral Fellow	2013–Present
Global Centre on Disaster Risk and Poverty	Director of Research	2012–2013
GlobalAgRisk, Inc.	Development Economist	2007–2012

Distinctions

United Nations Framework Convention on Climate Change Nairobi Work Plan Expert
University of Kentucky Dissertation Year Fellow (2011-2012)
John Redman Scholar (2008-2013)
Pass with Distinction, Agricultural Economics Qualifying Exam (2009)

Peer Reviewed Publications

Collier, B., and Skees, J. R. (2012). Increasing the Resilience of Financial Intermediaries through Portfolio-Level Insurance against Natural Disasters. *Natural Hazards* 64: 55–72.

Collier, B., Katchova, A. L., Skees, J. R. (2011). Loan Portfolio Performance and El Niño, An Intervention Analysis. *Agricultural Finance Review* 71: 98119.

Collier, B., Skees, J. R. and Barnett, B. J. (2009). Weather Index Insurance and Climate Change: Opportunities and Challenges in Lower Income Countries. *The Geneva Papers on Risk and Insurance: Issues and Practice* 34: 401–424.

Additional Publications

Collier, B. and Surminski, S. (forthcoming). Climate Risk as an Obstacle to Economic Development in Low-Income Countries. *Geneva Report*.

Skees, J. R., and Collier, B. (forthcoming). Climate Change: Risk Management Solutions for Developing Economies: A Portfolio Approach. *Insurance for Development*. Khn, D., ed. Heidelberg, Germany: Springer Verlag.

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