SWITCHING OPTIONS: THE VALUE OF FLEXIBILITY PROVIDED BY GEOGRAPHICAL DIVERSIFICATION

A Thesis
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

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In Partial Fulfillment
for the Degree of
MASTER OF SCIENCE

Major Department:
Agribusiness and Applied Economics

December 2013

Fargo, North Dakota

North Dakota State University
Graduate School

Title
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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

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ABSTRACT

The thesis develops a Monte Carlo simulation model with real options to value agricultural-commodity-trading firms' physical assets in relation to their existing networks of physical assets. The option value measured is the flexibility provided by switching options. This value can guide individual trading firms from an asset-light strategy towards more asset-medium/heavy and more profitable strategies. The thesis explores the value drivers for the optionality to switch origin locations. Optimal asset networks position traders to smooth imbalances in the market through spatial arbitrage. Further, the implications for contracting parts of the capacity, as well as how they affect the option value, are analyzed. The thesis provides a framework to understand the reasons behind recent mergers and acquisitions in the industry. The commodity analyzed in this thesis is soybeans across the United States, Ukraine, and Brazil with China as the destination market.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my adviser, Dr. Wilson, for providing me with the opportunity to research an important topic which has been, and still is, engaging and thought-provoking. Without his dedication, guidance, and knowledge regarding the topic, this thesis would never have been possible.

I would also like to thank Bruce Dahl for being helpful and able to shed light on any modeling problem, and to thank Kristopher Skadberg for helping me gather the needed data. My deepest thanks to my committee members, Dr. Larsen and Dr. Zhang, for their input and acceptance. Additionally, I would like to acknowledge how much I have learned by being part of the Agribusiness and Applied Economics Department at NDSU.

Last but not least, I would like to thank my family for always helping me move forward and to thank Zakia Triffi for the endless spellchecking.

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CHAPTER 1. INTRODUCTION

Problem Statement

An important aspect for commodity-trading firms is profitability. When reading the financial news, it is easy to see a surge in acquisitions by commodity firms. It is predicted that many commodity traders are going to continue their acquisition and investment binge in their search for profits. This venture might lead to the largest industry transformation in 30 years (Meersman, Reichtsteiner, & Sharp, 2012). This change can, in many ways, be seen as an adaption to the new information society, where traders can access and incorporate enormous amounts of data in a matter of seconds. Earlier, this information translated into profits. Shown by the success of the Dutch East India Company and Arab Silk Route merchants, profit was achieved thanks to knowledge about transportation routes and price information from different geographic locations.

Because reliable information is distributed quickly and accurately, this information no longer translates into the same advantage. According to Meersman Reichtsteiner, and Sharp (2012), commodity traders looking for success today need to master optionality. They thrive because they can offer more attractive prices to both producers and consumers. Commodity firms achieve this goal by managing their options in relation to location, time, quality, lot size, and the logistics of sourcing or delivering the commodities. In essence, commodity traders make large parts of their revenue from imbalances in supply and demand, not from speculation or high prices. The traders' vast networks give them a strong position to ease these imbalances and profit from the arbitrage.

Competition is increasing as more producers, commodity traders, and consumers try to capture these arbitrage opportunities. Because the competition is hardening, one way to gain an edge is by controlling physical assets. With control over logistical assets, commodity firms can take advantage of arbitrage opportunities while locking others out (simply by not granting access to the asset). Meersman et al. (2012) name this arbitrage potential the "total value of optionality" and define it as the absolute value of the commodity, the volatility of its price, and the frequency and magnitude of events that disturb the dynamic equilibrium of the market. It is also referred to as grey-swan events (a concept derived from the Black Swan Theory).

The Black Swan Theory defines unexpected events of large magnitude as well as their consequences and dominant role in history. Such Black-Swan events, considered extreme outliers, collectively play larger roles than regular occurrences (Taleb, 2008). On the other hand, grey-swan events can be anticipated to a certain degree, but are considered unlikely to occur and may have a sizeable impact on the market for a commodity. By their nature, black-swan events should only occur at unpredictable intervals. However, PricewaterhouseCoopers (2011) argues that these events happen more frequently. Rather than being infrequent outliers, they can be seen more commonly as a part of a faster-changing and more complex world. These changes create more uncertainty through the complex impact of grey-swan events (PricewaterhouseCoopers, 2011). Commodity traders might not be able to predict what will cause these events or the magnitude of price discrepancies that will be created, but the firms can assume that the events will happen.

Handling Black-Swan events, is not the only way a large network can help a commodity trader. CHS Inc. (CHS) traders benefit from the ability to mix and match multiple shuttles at any given time in accordance with the market. This network makes it possible to exploit small differences in price throughout their origination areas, as well as to sidetrack problems such as a blizzard-blocked train that is full of corn (by simply redirecting another train), and to take advantage of arbitrage opportunities. This flexibility not only creates profit opportunities, but it also increases the likelihood of honoring contracts and maintaining relationships with buyers (Richter, 2012).

This option to reroute shows that size matters across all physical trading markets. Whoever reacts fastest to an arbitrage opportunity can capture profit. To take full advantage of this optionality, traders need global coverage. Traders monitor the worldwide supply and demand. From this monitoring, arbitrage opportunities are found. Generally, traders do not profit from the ups and downs of the market but rather from the price fluctuations between locations. A push for infrastructure investments, combined with tight markets that are fueled by the economic boom in the emerging markets, has helped drive the expansion of commodity trade (Blas, 2013a).

Commodity traders as a force (or invisible hand) helping markets remove the imbalances in demand and supply might sound foreign, but the role as speculators is relatively small for many commodity firms. The increased correlation of commodities to other financial assets, have made supply and demand analysis less critical, because the market depend more on other factors. The increased amount of available information has also decreased the physical trader's edge over pure financial traders in the derivative markets for commodities (Terazono, 2012). According to a former physical energy trader, traders used to enter some physical transactions purely to obtain more information than everyone else (Terazono, 2012).

Industry executives believe that billions of dollars' worth of grain-trading assets will change hands (Blas, 2012a). These shifts will be the largest transactions since Cargill bought Continental Grain in 1998, and ADM and Noble bought assets after André & Cie's collapse in 2001. These acquisitions are seen by some as the beginning of the agricultural market's turnaround. Only since the food crisis in 2007-08 has international trade boomed and been accompanied with rising profits (Blas, 2012a).

According to United States Department of Agriculture (USDA), global exports of wheat is up by 40% since 2000. The corn export is up by 25%, and soybean sales overseas are up by 66%. As a real-world example, Glencore is currently digesting the Viterra deal. Glencore is now strong in Canada, the Black Sea region, and Australia. To obtain a position where all major markets can be used in arbitrage strategies, Glencore still needs locations in the United States and Brazil. The company has already indicated an interest for expansion into the U.S. market. The Viterra deal is a good approach to show how highly these geographical expansions are valued. The shares were finally taken over for a 45% premium relative to the stock price before the first announcement about the intent (Blas, 2012a)

This premium shows how these companies are geared towards the acquisition of physical assets. It is easier to see how acquisitions are beneficial with an example. By looking at the earthquake and tsunami that hit Japan in 2011, we can see the benefit. Natural-gas prices increased sharply because a nuclear power plant failed and gas-powered plants had to substitute the electrical generation (a Black-Swan event). Commodity giants such as the Gunvor Group could re-route liquefied gas shipments across the globe towards Japan and profit from this nuclear disaster. The regional traders could not take advantage of this opportunity because they only had access to the local gas market where the price already had increased. When the international commodity-trading firms shipped gas there, the price leveled off and went back to a more normal range that was only 10% higher than the prices before the disaster (Meersman, Reichtsteiner, & Sharp, 2012).

This acquisition hunger stems, in a large part, from a desire to take greater advantage of spatial arbitrage. Spatial arbitrage is simply arbitrage on price differences at various locations. Therefore, the rest of this thesis will develop a method to determine the option value of investing in real assets over a diverse set of originating countries. More precisely, the valuation will be specific to a typical grain trader. For example, Glencore, which is now a large player in Canada, the Black Sea region, and Australia, will have a different option value for physical assets in Brazil than a grain trader with its asset base in the United States and the Baltic region. This option value will depend on the arbitrage opportunities between the origination markets, i.e., the locations from which the commodity trader will source its commodities, and the respective destination markets. For simplicity, we will assume that there are several origination locations and one sale location spread over four geographical markets: the United States, Ukraine, and Brazil (origination) as well as China (destination).

Objectives

The primary objective of this thesis is to develop a model to determine the option value of investing in real assets over a diverse set of originating areas. Both for traders developing an optimal network, and for a typical grain trader that already has an existing network. The former has to find assets that create the best arbitrage opportunities. The latter seeks to add assets in the geographic locations that best complement the existing network, therefore extending the spatial-arbitrage reach. This option value is important because grain-trading firms are increasingly seeking geographic diversification (and investment strategies) to exploit the option value of being able to originate and operate at multiple origins. The thesis identifies the net present value, standard deviation, and distributions of return for various origination networks among the United States, Brazil, and Ukraine. The trading firm in question is shipping to Qingdao, China. Further, the thesis illustrates the underpinnings of flexibility that are embedded in physical assets and how changing market conditions affect these values. A discussion about expansion strategies for a specific trading network is also included. The major goal is to expand the current literature with an application of real options for international grain trade and to develop an understanding about the optionality embedded in grain elevators which can guide trading firms towards optimal management strategies and can aid in the search for physical assets.

Intrinsically, this model will find the value of the option to engage in spatial arbitrage between the U.S., Brazilian, or Ukrainian origination and the Chinese destination. This arbitrage model will, in essence, find the asset value in the United States, Brazil, and Ukraine for this specific firm's portfolio. Clearly, the managers of an optimally managed firm will seek assets that provide the most value. Finding the optimal asset combination is, therefore, the underpinning of a commodity trader's expansion strategy.

Specific Objective

i. Review previous studies relating to (1) spatial arbitrage in international commodity markets, (2) economies of scale and vertical integration, (3) asset ownership, and (4) recent mergers and acquisitions in the industry.

ii. Develop a real-option model to evaluate the profitability of physical assets, allowing traders to participate in spatial arbitrage around the international markets. The model values physical assets both as standalone (individually operated) assets and as part of a larger trading network (where assets are jointly managed).

iii. Use the modeling results to evaluate real-option strategies for investing in physical assets across geographical regions.

Procedures

To reach the objectives listed above, a real-option model with stochastic variables was developed to evaluate spatial-arbitrage opportunities in the global soybean trade. The real-option model determines the option value for investing real assets in a diverse set of originating locations. Specifically, the model values the asset by itself and as part of a larger network. This method gives the value of an elevator's ability to ship grain, both as an individual asset and as part of a larger network of assets. Elevators valued as part of a network (in this framework) incorporate the value of the option to change the origin location based on market moves (the optionality to switch). Networks valued without accounting for this embedded flexibility will inherently be undervalued.

The model has three different valuation attributes: (1) valuing each elevator separately, (2) valuing each elevator as part of the network, and (3) finding how these values change in relation to managerial decisions. It is important to point out that the model quantifies two different types of integration. A trader serving the Chinese market can be used to illustrate the integration. The trader can vertically integrate backwards through the value chain to an export elevator located in the U.S. Gulf. The trader can then vertically integrate backwards from the export elevator by acquiring country elevators (that are able the ship to the Gulf's export elevator). Alternatively, the trader can also acquire another export elevator located in the Pacific Northwest; this last acquisition would then be horizontal integration because the export elevator in the Gulf is on the same level. (i.e., the integration is on the same level.)

A review of the literature pertinent to international trading with a focus on commodities and grain has been evaluated. Studies about spatial arbitrage are reviewed because this concept is key for the model. Further, the focus lies on the economies of scale realized in the grain-trading business as well as the impact economies of scale has on the grain industry's structure both in the past and in the future. Finally, the structure and ownership of grain-handling firms and assets, as well as an evaluation of the industry's previous mergers and acquisitions, are documented.

Important data pertaining to the grain origination and logistical decisions were identified. Using these data, prototypical grain traders were modeled using a real-option model. The model was developed in a Microsoft Excel spreadsheet using the @Risk stochastic simulation software. The results were then used to determine the option value for the physical assets in question. Simulating the model defines the expected risks and returns for alternative expansion strategies.

Organization

Chapter 2 provides a review of literature for studies pertinent to international trading and spatial arbitrage. Subsequently, the structure and ownership of grain-handling firms and assets are documented. Afterwards, the chapter provides an investigation regarding recent acquisitions, including the background and the stated reason for the transactions. Chapter 3 goes through the theoretical model and concepts pertinent to real options as well as their use to analyze asset investments. Chapter 4 gives a description for the Empirical Model and stochastic simulation procedures regarding the valuation of potential assets. Chapter 5 presents the Results of the model and a sensitivity analysis of the key variables. Finally, Chapter 6 provides a summary of the study, including the implications for commodity-trading firms and future studies.

CHAPTER 2. BACKGROUND AND PREVIOUS STUDIES

This first section focuses on arbitrage, and why physical assets are important in this strategy and for the commodity firm's profit margins. Spatial arbitrage is the basis for international grain trade, and the underlying value behind the different optionalities that commodity traders seek to capture by geographical diversification (which this thesis seeks to value). The following sections focus on the economies of scale that commodity-trading firms may realize and why one of the economies of scale might be disappearing. These changes lead commodity-trading firms to reorganize with mergers and acquisitions in order to best manage the options to continuously thrive in the marketplace.

Spatial Arbitrage

Textbook arbitrage in a financial market requires no capital and entails no risk. In reality, almost all arbitrage requires capital and is risky, at least to some degree. The traditional definition of arbitrage is as follows: "simultaneous purchase and sale of the same, or essentially similar, security in two different markets for advantageously different prices" (Shleifer & Vishny, 1997). Theoretically, this type of arbitrage requires no capital and entails no risk. When the arbitrageur sells the more expensive contract and buys the cheaper one, the net future cash flow is zero because the profits are received up front. Arbitrage is an important factor in a marketplace because it, in effect, brings the prices to fundamental values and keeps the markets more efficient (Shleifer & Vishny, 1997).

In many cases, such completely risk-free arbitrage does not exist. In risk arbitrage, the probability of profits may not be 1 and most of all, arbitrage may need substantial amounts of capital to both execute the trade and cover potential, unforeseen losses (Shleifer & Vishny, 1997). It is easy to see how the existence of risk is relevant, especially for grain-trading firms, with the examples mentioned in Chapter 1. During the earthquake and tsunami that hit Japan in 2011 and caused a nuclear power plant to fail, and subsequently gas prices to skyrocket. The Gunvor Group could profit from this situation by selling gas in Japan, by locking in the price through sales contracts, and by rerouting or buying cheap gas in different locations and then transporting it to the sales location. To take part in this arbitrage, significant capital is needed. In terms of physical assets, the Gunvor Group needs facilities to load, transport, and receive the gas; the company probably needs cash to lock in the contracts or to pay for the shipping.

On the other hand, there are potential unforeseen losses. How spatial arbitrage requires capital and a large network of assets over large geographical areas is easy to see with the second example from Chapter 1: every week, a senior corn merchandiser at CHS has 20 or so shuttles that he can mix and match as the market dictates. If the trader was in an arbitrage trade when the shuttle traveling to the destination with a higher corn price was blocked by a blizzard, the result could be a large loss This blizzard could have potentially forced him to take a loss and buy the crop from someone else. Because CHS has a large network, he could simply redirect another shuttle train. This option requires large amounts of initial (physical) capital.

Trading firms seek arbitrage opportunities to an extent where it even affects their ownership structures. This hunt for arbitrage opportunities manifests itself in commodity trader's reluctance to be publicly traded (in addition to the obvious secrecy it allows). For grain trader who is publicly traded, an arbitrage strategy could have bad effects on stock prices. Let us assume a trader has an arbitrage position, however, the prices move further from the fundamental values. In this case, an arbitrageur would, in general, increase his position when the contracts move further out of line as long as he has the capital. When the arbitrageur manages other people's assets (due to a publicly traded firm), the shareholders will only see him lose money if they do not fully know or understand what he is doing. They may, therefore, assume that the grain-trading firm is not competent to manage their money and liquidate their funds to find a better investment opportunity even though the expected return from the trade has actually increased. When arbitrage requires capital and this capital is owned by an external investor, the arbitrageur might become constrained when the trades actually have the highest potential (Shleifer & Vishny, 1997). Shleifer and Vishny's (1997) model finds results in contrast to the traditional models, where arbitrageurs are most aggressive when prices are the furthest from the fundamentals; when external ownership of the assets is considered, the opposite actually happens. The defining factor is the ownership structure.

Transfer Costs

Baulch (1997) shows the importance of transfer costs with spatial arbitrage. Market prices across different regions vary in several cases. This difference does not imply spatial-arbitrage opportunities because transfer costs must be included. The model uses transfer costs and food prices to judge the efficiency of spatial arbitrage. Price signals do not transfer from urban areas with a food deficit to rural, food-surplus areas without spatial integration of markets. This price transfer is the essence of commodity arbitrage. Price transfer stabilizes prices and makes producers specialize in according to competitive advantages, and gains from trade are realized. Many researchers have studied this integration; by looking at price data alone, they fail to recognize the pivotal role of transfer costs.

Spatial arbitrage should occur every time the inter-market price difference exceeds or equals the transportation costs. Baulch (1997) uses the parity-bounds model (PBM). This model allows for three different scenarios: (1) the spatial price difference equals transfer costs; (2) the price difference is less than transportation costs; and (3) the price difference exceeds transfer costs. Arbitrage would happen in scenario 3. Theoretically, scenario 3 occurs whenever Equation 1 holds true, where P_t^i represents the origin market, K_t^{ij} represents transfer costs, and P_t^j is the destination market price.

$$P_t^i + K_t^{ij} < P_t^j \tag{1}$$

Because this model uses Monte Carlo Simulation, it allows for markets to be linked by discontinuous trade flows. Further, it must not make assumptions about the traders' marketing margins. However, this modeling type could indicate arbitrage when it is not actually happening. This overestimation of arbitrage could, for example, be due to logistic bottlenecks or governmental intervention halting arbitrage in the real world (Baulch, 1997).

Coleman (2009) found considerable variation in transport prices due to demand hikes where transport needs exceed the capacity limits. From this capacity constraints, prices vary over time in different markets, meaning that the law of one price still holds as transport prices change. Shipping shortages might arise from a local shuttle shortage, port congestion, or barge shortages. The model incorporates storage, uncertainty, transportation constraints, and transport time. Storage is included because it provides arbitrageurs with the option to store and ship at a future time when shipping prices are lower. Coleman (2009) argues that transport price is equal to the marginal transport price when the amount shipped is under full capacity; if the shipping amount is exceeded, the price equals the difference between the simultaneously determined spot price at the exporting location and the discounted, expected future price at the importing market. These findings imply that supply-and-demand shocks in the commodity market actually lead to endogenous variations in the transport costs (Coleman, 2009).

As an argument for increasing physical assets, a grain trader can simply adjust inventories to smooth the minor imbalances between locations. During this adjustment period, the price difference is less than or equal to the marginal transportation cost, adjusted for storage costs. On the other hand, if the shock is large, inventories are run down and new inventories will be shipped. Then, in the short run, the goods do not arrive immediately and the spot price at the importing location could exceed the price at the exporting location and the transportation cost. However, shipping companies will attempt to exploit the expected high price, therefore driving up the shipping prices, until it equals the price difference between locations. By having control of the shipping assets, grain traders could benefit from the expected price for a longer time as the profit moves from the arbitrageur to the shipping assets' owner (now the commodity trader).. This profit transfer gives insight for the correlation between commodity prices and transport prices when capacity constraints are present (Coleman, 2009).

Coleman's (2009) model shows that trade flows, including transport prices, storage quantity, and commodity prices, vary significantly as the transport capacity changes. The effect of a price shock is larger on a geographical area if the transport capacity reaches its limits. This model shows the importance of the commodity firms' waste transport capacity; it enables them to profit by soothing the imbalance (Coleman, 2009). This dependence on logistic networks, again, goes back to Japan after the earthquake and tsunami. The Gunvor Group (including others) could then bring the price of liquefied gas to only 10% higher than previous to the disaster by increasing the supply through increased arbitrage trade (and, at the same time, profit in doing so).

Evolution of the International Commodity-Trading Business

Commodity firms are, in many cases, based in jurisdictions with low taxes and little regulation. Combined, they provide more than one trillion dollars in revenue and trade more than half the world's commodities. They are steadily expanding and own assets, such as production assets, ships and pipelines, warehouses, silos, and ports. Their physical assets allow them to benefit from political events, such as the violent political crisis in the Ivory Coast which limited cocoa exports (Schneyer, 2011).

Asset Ownership

Commodity traders vary from firms that rely heavily on physical assets (Rio Tinto and Exxon Mobile) to traders with a low reliance on physical assets (Vitol and Trafigura) and the middle range (Archer Daniels Midland (ADM) and Cargill). This reliance is measured in terms of fixed assets over revenue (Meersman, Reichtsteiner, & Sharp, 2012). Grain traders own facilities (assets) that include country, river, terminal, and export-handling facilities. Traders might also have options to use or directly own transportation modes and processing plants. However, this thesis focuses on soybean handling facilities (country, river, and export elevators). Over the past decades, storage capacity has increased dramatically.

The number of facilities operated by different companies increased quickly; for example, ADM increased this number from zero to 271 in a 10-year period (1985-1995). Large firms often own a set of facilities to integrate throughout the commodity chain, such as county elevators, sub-terminals, terminals, and river and port elevators (Wilson & Dahl, 1999). Wilson and Dahl (1999) also showcased several trends between 1980 and the following two decades; these trends illustrated an increased efficiency, especially for the loading capacity. For example, North Dakota saw a 16% reduction in the number of elevators, along with doubling the storage capacity and an increased loading capacity.

Mergers and Acquisitions

One change in the grain industry has been towards vertically aligned firms. Interestingly, it appears that the firms controlling more assets dominate. Reasons for the movement towards vertical integration might include (1) economies of transportation and handling, (2) greater logistical and quality control, and (3) strategic changes to mitigate the firms' market power elsewhere in the vertical market system (Wilson & Dahl, 1999). The first factor is of obvious importance for spatial arbitrage. When focusing on arbitrage, there might be another hidden benefit that we can see by looking back at Coleman's (2009) previously mentioned paper: by having control of the shipping assets, grain traders could benefit from the expected price difference longer (arbitrage opportunity) as the profit moves from the arbitrageur to the shipping assets' owner in the case of shipping constraints. In other words, when the shipping providers would benefit as the unintegrated arbitrageurs will have to bid up the shipping premiums, the trader owning shipping assets would just transfer the profits to another part of their trading chain (Coleman, 2009).

Economies of Scale

When it comes to the international commodity traders, it has been argued that they have two main advantages that cause economies of scale (Caves, 1977). First, the intangible economies of scale stems from the extensive information required to successfully engage in trade. Obtaining these data has historically come with a high fixed cost and could, therefore, deter entry to the industry. Second, the tangible economies of scale, which also comes with high costs (especially to acquire), consists of facilities such as storage, handling, and transportation (Caves, 1977). As mentioned earlier, at the present time, where price information is readily available through subscription-based data services, commodity firms might be losing one of their advantages, the intangible scale economies. As traders, producers, and consumers, to a higher degree, have access to the same information feeds in real time, one of the two major advantages might be evaporating. This reduction in the intangible economies of scale might, in fact, be one of the reasons for the commodity firms' hunger for physical assets, to protect their second advantage: the tangible scale economies.

Scoppola (2006) investigates the international grain trade by focusing on multinational commodity firms and their ability to take advantage of the economies of scale. Many large grain traders have control over all facilities, from the exporting to the importing country, involved in their transportation chain. This control allows the commodity trader to avoid the transaction costs that are rooted in negotiations with downstream operators (Scoppola, 2006). In an arbitrage situation, this reduction in transfer costs comes in addition to the prolonged profits that, with outside shipping providers, would have gone to the shipping company (Coleman, 2009).

Vertical Integration

Vertical integration, which occurs when one firm owns more than one stage of production, can be used as a means to realize greater economic value. For traders, vertical integration can give them a larger part of the economic value while, at the same time, allowing for greater quality and timing control. Vertical coordination is similar; however, the firm would capture the value at multiple stages of production without actually owning the assets. Vertical coordination is achieved by creating vertical coordination agreements at different stages in the value chain (Bylund & Hertzke, 2011).

Trading Firms and How to Control the Commodity Flow

Commodity traders' strategic moves secure trade flows. The traders will try to remain price neutral. The profit is found by moving large quantities around the world and securing low margins. Contrary to popular belief, commodity-trading firms are not a play on higher commodity prices; they are more a play on increased trade flows. Many traders will aggregate information and goods to operate supply chains and infrastructure. Some traders will even finance producers and customers. By managing their risk profile properly, traders can reach lower volatilities than producers or of the commodities they trade. Because many traders rely on market inefficiencies, transparency is generally not beneficial and might explain the private ownership structures (Wang & Li, 2010).

Because traders exploit the inefficiencies, many people might ask why they are still needed. Traders can match supply and demand, and serve as a trustworthy middleman. Many producers and consumers simply lack the resources or expertise to operate the infrastructure needed by themselves. Logistical bottlenecks may severely depress commodity prices in a geographical location. By controlling these bottlenecks, trading firms might be able to reap far higher margins. The three easiest ways to control trade flows are through the origination, logistics, or finances. Contrary to previous times, information becomes more transparent and, therefore, hard to control. First, origination can be controlled by acquiring commodity-producing assets such as plantations or farms. In some cases, refineries and crushing plants might be considered as origination assets by traders handling these processed commodities. However, producing assets are considered more risky because they depend more on commodity prices, have operational risks, and often need significant capital. Often, trading firms only take these production assets on at strategically important locations due to the risks involved.

Second, the control of logistics, which may be the oldest and most cost-effective way to control trade flows, is obtained by holding infrastructure such as railroads, ports, terminals, storage spaces, shipping vessels, and processing capacities. One reason for the cost effectiveness comes from the fact that storage can be leased, that ships can be time-chartered, and that terminals and ports can operate under long time contracts. The control provided by these assets at key nodes of the logistical chain, such as storage and processing plants close to ports or origination areas, can give strong leverage. This is especially true for producing agricultural commodities, such as grains, because this leverage is more effective against fragmented suppliers, such as farmers. This control of physical assets gives the best exposure to arbitrage opportunities.

The third way to control, which is the most remote to the thesis' topic, is controlling finances. A trading firm can control trade flows by helping to structure loans between the producer and a bank. Traders are credit-worthy and can guarantee the future performance of a producer by taking collateral in future commodity outputs (Wang & Li, 2010).

Commodity Trading Firms' Reliance on Physical Assets

The trading firms can be divided into three subcategories based on their reliance on physical assets. Each category has benefits and drawbacks. Trading in its purest form is price neutral and, therefore, different from speculating. Traders want to buy low and sell high, simultaneously maintaining a price- (risk) neutral profile. This approach relates most to asset-light traders.

Asset-light traders

Asset-light traders use industry fragmentation and information imbalances to their advantage while managing trade flows through contracts. This strategy is typical for a trader who functions as a middleman. By being asset-light, the trading firm maintains flexibility and needs relatively low capital outlays. The downside is often low margins, vulnerability to competition, and limited control of the trade flow (Wang & Li, 2010). These traders, such as Vitol, with low reliance on assets (fixed assets/revenue) often have a lower profitability (Meersman, Reichtsteiner, & Sharp, 2012). Due to the low capital requirements, this stage is usually where trading firms start, but as they grow, many start seeking control over assets and providing more control for the flow in their network (Wang & Li, 2010).

Asset-medium traders

One important difference between traders and producers is viewing a physical asset as a medium to control a trade flow. Production assets offer control for the origination, but they are often expensive. Therefore, commodity traders do not necessarily seek to own 100% of their assets; they need to maximize the utility of their capital which, in many cases, can be found by investing just enough to gain control of the commodity traveling through a logistical network. For example, a trading firm might take a minority stake in a crushing plant in exchange for rights to the commodities as a part of its strategy (Wang & Li, 2010).

Logistical assets, such as storage facilities, processing plants, ports, and terminals, are assets where the traders often seek majority stakes at key locations. A logistic chain with assets in key locations could be as follows: (1) storage facilities may be in the producing regions to collect the commodity ; (2) primary and intermediary processing plants are located close to the originations (helps reduce transportation costs by compressing volumes or allowing soybean meal to be separated from soybean oil for different markets); (3) gateway assets, such as terminals in commodity-producing regions or trading hubs, often yield the highest return; and (4) traders might own end-processing facilities, depending on cost and market access. This asset ownership, combined with a time-chartered fleet of vessels and shuttles, can be used to secure shipping (Wang & Li, 2010). Of the major physical assets, storage facilities, terminals, shuttles, and vessels have the most relevance in the spatial arbitrage on which our valuation of physical assets will be based.

Asset-heavy traders

Trading firms are considered asset-heavy when production assets contribute largely to their profits. Taking on origination assets has an interesting implication, disposure to the direction of commodity prices. Price neutrality would still exist in the physical-trading undertakings. However, assets involved with production are exposed to commodity-price fluctuations. As a reward for this increased risk, production assets supply stability, better margins, and an exposure to rising commodity prices.

Asset-heavy traders must decide whether they should develop assets or acquire established ones. Established assets are usually priced with a premium, but generally already have a cash flow. Asset-heavy traders are more volatile and also inheritably more profitable. This increased volatility stems from the cycles in commodity production. An example is Glencore (asset-medium/heavy), a company that experienced a 43% drop in net income due to lower commodity prices in 2009. The Noble Group (asset-medium) only experienced a drop of 4% in the same time period (Wang & Li, 2010). The Noble Group relies on assets approximately half as much as Glencore when measured in terms of fixed assets/revenue (Meersman, Reichtsteiner, & Sharp, 2012).

Noble Group: An asset-medium profile

To understand what being an asset-medium trader is, how to get there, or how to move towards being an asset-heavy trader, we can look at an example. The asset-medium Noble Group actively pursues the control of trade flows, not commodity productions. The relevant part of the Noble Group for this thesis is its grains and soft commodities branch which operates storage facilities, terminals, and some processing plants in Argentina, Brazil, Paraguay, Uruguay, Cote d'lvoire, the Netherlands, China, Indonesia, Saudi Arabia, Jordan, and the United States (Wang

& Li, 2010; (Meersman, Reichtsteiner, & Sharp, 2012). See Table 2.1 for a list of originations and destinations.

Table 2.1. Originations and Destinations for Noble Group's Grains and Oilseeds

Origination	Destination
South America, USA, Russia, Ukraine, South Africa, Australia	China, Europe, Middle East, Japan, Southeast Asia

The Noble Group's assets are placed in key gateway locations. The company has ten storage facilities, five port terminals, and three crushing plants across Argentina, Brazil, Paraguay, and Uruguay. This area functions as the company's main origination source. The main destination of these products is China where the Noble Group operates four storage and soybean-crushing facilities as well as one additional storage terminal (Wang & Li, 2010).

Because the thesis focuses on logistic assets, the model will be most valuable for asset-light trading firms that want to move towards an asset-medium strategy and for asset-medium/heavy traders that seek to expand their reach and arbitrage potential. Because asset-heavy traders rely largely on production facilities, this model can be used to expand traders' physical assets in the medium category.

The Noble Group's logistical assets also include 215 vessels. This fleet moved 64.5 million tons of goods in 2009 and contributed 16% of the company's total profit. This fleet services between 15% and 25% of the Noble Group's trading tonnage as well as third-party transportation needs. There are 10 fully owned and 205 chartered vessels. The Noble Group charters vessels with 1-year contracts when the market is beneficial; this strategy allows the company to benefit when prices rise. This fleet is pivotal because it protects the key shipping routes and provides flexibility when the market is cornered (Meersman, Reichtsteiner, & Sharp, 2012).

The Changing Future

Speculation

As the physicists, engineers, and mathematicians (also called quants) who stand behind more than half of all U.S. stock trading seek new profit-generating venues through ultra-high speed trading, many commodity-trading firms might lose some of their edge in the financial trade of commodities (Adler, 2012). As algorithms scan through the ever-increasing pool of news, market rumors (through Twitter, etc.), and weather and price data, the unique position of commodity firms as the fastest and most knowledgeable traders in the futures market might be at risk.

However, there might be a benefit after all, depending on how this high-speed trading actually impacts the market. There are generally two strains of thought: (1) high-frequency trading provides liquidity in the market, and (2) it creates uncertainty and a potential for large price movements when something goes wrong (Adler, 2012). Both scenarios can actually benefit a trading firm when dealing with physical trade. If the former is true, there will be easier-to-hedge risks incurred in the physical market. If the latter is true, traders can benefit from the uncertainty by utilizing discrepancies between the futures market and the spot prices at different locations through arbitrage. Either way, physical assets are key.

Another element that could affect prices is the enormous inflow of institutional money from pension funds, university endowments, etc. This amount of investments increased from a mere 13 billion dollars to 260 billion dollars in the 5 years leading up to 2008. Historically, the individuals who wanted to invest in commodities invested directly in a producer or a mine. Today, this capital is invested directly in the commodities through index funds, and the investors are considered speculators (Dugan, 2008).

Kaufman (2010) argues that the grain exchanges previously benefitted from the speculators because the exchanges provided farmers and millers the freedom to buy and sell their actual wheat in a liquid market; the speculators provided a steady flow of buy and sell orders. The key difference between the past and the current speculation is the part where the speculator closes out the position. Goldman Sachs was the pioneer for this new form of speculation with its so-called Commodity Index. This index consists of funds rolled over from contract to contract into the future with no intent of closing out the positions. Goldman Sachs' Commodity Index does not buy low and sell high, but rather keep buying. This purchasing behavior has two sides, one for Goldman Sachs and one for the market itself. Goldman Sachs buys futures for its clients, however, the company only needs to deposit the margin requirement, and the rest of the money is invested on the bank's behalf in more secure venues, therefore providing an inflow of capital and administration fees simultaneously. The investor gets exposure to the futures market. On the other hand, for the market, the purchases creates a form of a demand shock; the index fund buys commodities that it never intends to receive, that do not exist, and that never need to exist. In essence, the strategy corners the market. Many people attribute this demand shock as one of the major causes for the recent increase in market volatility (Kaufman, 2010).

Abundance and Demand

With the population growing at 1% per year or more, there might be a limited margin in the food supply. Even with the increased use of fertilizer, crop yields per acre have declined from 3.5% in 1960 to 1.2% today. This yield reduction, combined with preferences changing towards more meat consumption, influences the prices. Grantham (2011) shows how this demand increase resulting from growing wealth and population has influenced all commodity prices. All major commodities have decreased in price by more than two-thirds from 1900-2002. However, from 2002-2011, this decline was reversed with a larger price increase than the world experienced during World War II. This astonishing price hike might be partially understood by looking at China. China consumes 53.2% of all the world's cement and 47.7% of all the iron ore (Lubin, 2011). Even though the numbers are not as high for agricultural commodities, China still consume 46.4% of all pigs, 16.6% of the wheat, 37.2% of the eggs, 28.1% of the rice, and 24.6% of the soybeans (Grantham, 2011).

Another argument for a change in the trend regarding commodities is the implied probability under the assumption of a normal price distribution and where the prices are now. By using this method, wheat has a 1 in 120 chance of being this far over the trend for the past 100 years. Soybeans have an even more extreme deviation from the trend with a probability of 1 in 1,000. As developing countries consume an increased portion of the agricultural commodities, the question of resource constraints comes to play. Even though there is plenty of land available, there is a big gap in output for different land qualities. High-quality land with a high yield is limited, and Ukraine and Brazil sit on most of the untapped potential (Grantham, 2011).

Grantham (2012) argues that we are 10 years into a paradigm shift marked by increasing demand and rising resource prices as the population pushes towards 9 billion (projected to be a reality in 2050). This population increase implies that the world will need a 60-100% increase in the food supply to provide a modest amount of calories for the entire population. This situation will obviously put pressure on prices. This problem can be magnified by the projected climate instability. When supplies have little margin and small reserves, supply changes could have relatively big effects. More floods and droughts are projected as the average temperature rises (due to global warming caused by humans or simply by a naturally changing temperature cycle) (Grantham, 2012). An example is the drought in the U.S, Midwest which helped push prices up by 50% in one month. According to the National Oceanic and Atmospheric Administration, the chance of this drought not being influenced by a warmer climate has a probability of 1 in 1 million (Grantham, 2012). These changes are obviously a challenge, but the potential instability could also increase the value of physical assets that offer the option to ship from different locations as production becomes more unstable, and as the higher population growth pressures the demand. The increasing potential for price instability makes the topic of this thesis even more relevant: what is the value of the option to ship from an additional location?

Clearly, commodity traders face a changing environment. One of their major economies of scale is disappearing; market volatility is increasing; and prices are increasing due to changes in the nature of speculation and population growth. Relating back to the Black Swan Theory and the increase in the frequency of so-called grey-swan events, and the increase in predicted market volatility. Commodity-trading firms might not be able to predict when and how arbitrage opportunities will arise, but in anticipation of greater market volumes and uncertainty, the key to the firms' success lies in gaining control of trade flows and managing the options that these trade flows (and the assets creating them) provide. Several trading firms already strive to capture these opportunities by means of mergers and acquisitions.

Mergers and Acquisitions

Grain traders are experiencing some major changes. The most prevalent trends are the changing composition of firms, vertical integration, mergers towards value-added processing, joint ventures, more focus on biofuels, and an inflow of private capital. The most prevalent change for this thesis is through vertical integration. The commodity firms used to be vertically disintegrated and were only linked through market transactions. Lately, firms have moved towards greater logistic and market control. These strategies seek to expand market power into the vertical system (Wilson W. , 2012)

Because the commodity market is becoming more competitive, trading firms might seek to gain physical assets that can boost profits. The sector's return on equity has dropped from around 50-60% in 2005 to about 20-30% now. An example is Glencore which has seen a drop in profits from 61% in the early 2000s to 9.7% in 2012 (Blas, 2013b). Mergers and acquisitions often provide economics of scale and a strategic advantage. As the commodity firms move upward in the supply chain, they gain a reliable, long-term supply and manage counterparty risks. Commodity prices have also seen previously unheard of volatility levels which increase the counterparty risk. However, with a secure and vast network, these same volatilities can provide arbitrage opportunities. Four-sigma price movements illustrate this increased volatility well because, statistically, they should only occur once every 120 years. In 2011, four-sigma moves happened 4 times (Ching & Lau, 2012).

As the traditional middleman-role business faces more competition and falling margins, the trading firms shift towards vertically integrated companies that operate transportation, production, and distribution by acquiring physical assets (Farchy, Terazono, & Blas, 2012). To illustrate the surge in acquisitions three separate cases are highlighted: ADM's bid for GrainCorp, Marubeni's acquisition of Gavilon, and Glencore's purchase of Viterra.

ADM's Bid for GrainCorp

GrainCorp is the largest grain handler and exporter in eastern Australia. According to ADM's internal communications: "GrainCorp would make an excellent addition to ADM's global network, with a geographic footprint and grain handling, marketing and processing operations that complement our existing assets" (ADM, 2013). The most relevant quotes for this thesis relates directly to potential arbitrage opportunities: "provides a strong origination platform that adds to our geographic diversity" (ADM, 2013). When the takeover is finalized, it would include 280 country elevators, 7 export elevators, and transportation assets. In addition, several processing facilities would also be part of the takeover.

To illustrate the perceived worth of GrainCorp as a part of ADM's network relative to GrainCorp as a standalone company, the data around the $12.20 per-share bid can give a strong indicator. The bid represents

- A 49% premium to the closing price before ADM's first approach to GrainCorp on October 18, 2012.
- A 44% premium to the 3 month (volume-weighted) average for GrainCorp shares up to October 18, 2012. (ADM, 2013).

Marubeni's Acquisition of Gavilon

Tokyo-based Marubeni is acquiring Gavilon (minus its energy unit) for $2.6 billion; the Japanese trading firm also takes over Gavilon's debt (somewhere under $2 billion). This purchase gives Japan's biggest agricultural trader the option to originate corn and soybeans from a wider geographic area and will, therefore, allow it to better compete with Cargill (the largest grain handler in the world and one of the biggest importers to Asia). The takeover will more than double Marubeni's grain-handling volume to over 55 million metric tons/year and add 140 grain-loading facilities to the company's portfolio. This acquisition gives Marubeni the most important option, the option to source grain from more locations, namely Brazil, Australia, Ukraine, and the United States (Humber & Suzuki, 2013). Acquiring Gavilon gives Marubeni critical exposure to the major origination markets and will secure supplies for its home market. Greg Heckman (the president and chief executive of Gavilon) stated that, as a part of a larger trading network, Gavilon would be better positioned to connect its supply with the growing global demand (Tabuchi, 2012). The deal has also been seen positively by analysts because Gavilon's position in the Central Plains and Midwest complements Marubeni's position in the Pacific Northwest through the shortest sea route connecting the United States and Asia (Emoto & Soyoung, 2013).

Glencore's Purchase of Viterra

Glencore is heavily acquiring assets to move away from its middleman business model (Blas, 2012b). Its largest expansion into grain handling has been buying Viterra's assets for $6.2 billion. This network of physical assets includes marketing and distribution resources in Canada, the United States, Australia, New Zealand, and China. Viterra controls 45% of the grain trade in Canada (the sixth-largest grain-exporting country) and a large operation in Australia (the third-largest grain-exporting country). Glencore, which is already the largest commodity trader in the world, will gain origination power, get control of strategic trade flows, and gain exposure to the growth potential in China (Dummett, 2012). This acquisition dramatically increases Glencore's geographical reach (Donville & Riseborough, 2012).

According to Glencore and Viterra's media release, the acquisition will give Glencore a critical mass in the key grain markets of North America as well as expanding Glencore's existing operations in Australia. Chris Mahoney (Glencore's director of agricultural products), stated that, by combining Viterra's first-class assets in grain logistics and processing with Glencore's global-marketing capability, Glencore has the opportunity to become a true leader across the sector (Viterra, 2012). The logistic assets that Glencore take over includes 7 port terminals and 92 grain elevators (Cross, 2013).

To see how important and highly valued the option to originate from diverse geographical locations is, this acquisition can give some insight. Viterra, which never officially was for sale, was approached by four different companies that wanted to integrate Viterra into their trading systems. The $6.2-billion (or $16.25/share) deal had a premium of 55% over the average price in the previous 20 trading sessions before the deal was announced on March 20, 2012 (Hasselback, 2013).

The Key Factor

The key factor here, in all the acquisitions, was to increase the optionality in the origination and destination markets. The premiums paid for these physical assets clearly showed the perceived value. As we saw earlier, with changes in economies of scale (from new information flows) and the changing future through new forms of financial trading (which might remove the physical traders' edge in the financial markets), commodity traders must maintain their advantage through careful management of logistical assets, supply contracts, purchasing agreements, and processing facilities.

For example, there are different standardized contracts for grain, specifying properties such as hardness and protein. These contracts often trade at different prices; a physical trader can blend high-quality grains with low-quality (and cheaper) grains to meet the requirements of a contract trading at a premium with the maximum amount of grains (Meersman, Reichtsteiner, & Sharp, 2012). Physical assets give an advantage neither financial traders nor information can take away; this advantage is through the tangible economies of scale. The future winners will be the commodity firms that can develop these systems at the lowest cost and that can manage their optionality best.

CHAPTER 3. REAL OPTIONS AND GEOGRAPHICALLY DISPERSE ASSETS

Introduction to Real Options

Monte Carlo Simulation can be used to identify, predict, and quantify risk. This quantification and understanding of risk has a natural extension through real options. Real options allow for the valuation of risk, the creation of strategies to mitigate risk, and the knowledge about how to position oneself to take advantage of risk. In essence, real options permits the transformation of this information into tangible strategies. In simple terms, real options can be considered a systematic approach for valuing physical assets based on financial theory, economic analysis, management sciences, statistics, and econometric modeling (Mun, 2010). Real-options analysis (ROA) is a method of valuing flexible strategies under uncertainty (Alizadeh & Nomikos, 2009). ROA seeks to find the full value of investments under uncertainty. It provides a bridge between strategy and finance (Gitelman, 2002).

ROA is a natural extension for financial options which can be used to value flexibility and optionality with investments and operational projects. This thesis values the optionality and flexibility provided by owning physical assets across the Pacific Northwest, The U.S. Gulf, Brazil, and the Black Sea region of the Ukraine for a commodity trader serving the Chinese market through the port of Qingdao. Traders managing origination assets across several regions have additional flexibility compared to traders with only one origin. The flexibility is the optionality to originate from multiple markets and, therefore, to increase the probability of spatial-arbitrage opportunities (assuming each market, in fact, has different price distributions). Real options can value this opportunity.

Real Options Relative to Financial Options

Real options come from the observation that actual investment opportunities, not just those involving stocks, can be valued as a combination of puts and calls. For example, suppose someone can buy a factory 3 years from now for $50 million. Let P equal the value of the factory 3 years from now. This value is highly uncertain and depends on factors such as the overall economy, fuel prices, commodity prices, etc. As a result, the cash flows 3 years from now would equal MAX (P-50,0). This payoff is precisely the same equation used to define a call option with an exercise price of $50 million. Because one can value a call option of this form, one must also be able to value an option to acquire a factory in the same way (Winston, 2008).

Even though the theory behind real options builds on the financial option theory, there are several differences. For example, with real options, the underlying variables come from cash flows affected by the company's decision-making process. Financial options, on the other hand, have tradable financial assets as the underlying variable. The maturity of these options is often short, and they can also be traded on the secondary market. However, real options are embedded values in projects, often over longer periods of time, and generally cannot be traded. One major difference is that the option premium for financial assets cannot be controlled by an investor while premiums for real options depend on the projects' flexibility and strategic optionality. In principle, investors' assumptions and actions for financial options should have no influence on the option value; this absence of influence is not the case for real options (Alizadeh & Nomikos, 2009).

Despite these differences, it is possible to value both option types with binomial valuation methods and simulation techniques (Alizadeh & Nomikos, 2009). General option valuation is based on securities with an equivalent risk and known market price. ROA focuses on real assets that often do not have equivalent markets. As a substitute, this method relies on proxies from other markets, such as the commodity markets, financial instruments, and stocks for companies facing similar risks (Gitelman, 2002).

Discounted Cash Flow (DCF) vs. Real Options

Real-options analysis seeks to maximize market value. The main difference between real-options analysis and discounted cash flow (DCF) analysis is that real options consider how decision makers should use all available information, even what is revealed over time. DCF analysis, on the other hand, only uses the information available at time 0 which, therefore, makes decisions (and if they are profitable) years in advance and forces the decision maker to follow through with the plans regardless of new information revealed over time and based on the current net present value (NPV). Hence, real options should be used whenever a decision-making process goes on over time (Guthrie, 2009). Consequently, DCF can, in many cases, fail to value several factors that could influence the project, such as managerial flexibility, different paths that might be available at a later point, and uncertainty around future cash flows (Alizadeh & Nomikos, 2009). These limitations are the reason why real options fit this project. Indeed, there is an embedded option to switch between origination locations in a network of grain elevators.

Instead of relying on a static discount rate to calculate the present value of cash flows from all potential choices, real options recognize the risk in cash flows created from dynamic decision making. In essence, this recognition should leave valuation to the market through estimation of the market value of each cash flow by finding a portfolio of traded securities that generates the same cash flow. This portfolio uses the observed market value as an estimate of the cash flow. In other words, it is a method to create a replica portfolio and which is then used to estimate the value (Guthrie, 2009).

Types of Real Options and Option Styles

ROA can be subdivided into analyses involving different types of real options, including the abandonment, barrier, expansion, chooser, contraction, deferment, and switching options. For an overview of the major categories, see Table 3.1.

Table 3.1. Types of Real Options (Mun, 2010)

Real-Option Type	Description
Abandonment Option	Provides the right, but not the obligation, to sell (and abandon) a project or asset.
Barrier Option	Provides the flexibility to execute an option when an artificial barrier is breached. The value, therefore, depends on this breach happening or not.
Expansion Option	Provides the right and option to expand into different markets, products, strategies, or the current operation given beneficial conditions.
Chooser Option	Provides the flexibility to choose between strategies, such as the option to expand, abandon, switch, contract, and combinations of other exotic options.
Contraction Option	Provides the right and ability to contract (outsource) operations if given the right circumstances.
Deferment Option/Option to Wait	Provides the right to wait until more information is available at a future point.
Sequential Compound Option	An option where the value of future strategic options depends on previous options in the sequence.
Switching Option	Provides the right and ability to switch between operating conditions, such as different technologies, markets, or products.

Every option in Table 3.1 can be modeled with different execution times, including American, European, Bermuda, and Asian option styles (Mun, 2010). See Table 3.2 for an overview of the different execution times.

Table 3.2. Option Styles (Mun, 2010)

Option Style	Description
European Option	May only be exercised on expiration.
American Option	May be exercised on any trading day on or before expiration.
Bermudan Option	May be exercised only on specified dates on or before expiration.
Asian Option	Payoff is determined by the average underlying price during some preset time period.

To find the appropriate ROA model, one needs to go through the different types of options and option styles to find the correct way of modeling the value of physical assets that opens for arbitrage play. In other words, model the value of the optionality to originate from different locations, allowing the commodity trader to take advantage of a given market's spatial-arbitrage opportunities.

The Optimal Option

The goal of the thesis is to develop a valuation method for the physical assets that give optionality for origination or the ability to switch between locations. The physical assets, thus, provide a switching option. This option (the physical assets) is essentially providing cheaper access to a resource over a given period of time (by switching when the market is favorable). The commodity trader wants to value this right to originate from additional locations. He would correspondingly acquire the option if the cost (of the physical asset) is outweighed by savings from switching origination locations as the commodities become cheaper in a particular region. By spending the additional money to acquire these assets and maintain their minimum running costs, the commodity trader has essentially paid the premium for purchasing a switching option which is important, especially when crop prices fluctuate between regions. This option provides a right to arbitrage.

It is important to remember that the physical assets also have revenues and cash flows as standalone assets. By using real options, the strategic options that come with the physical assets will also be valued. The switching option is not necessarily the only option embedded in the asset even though it is the main focus. For example, if the acquired asset does not perform as expected, it might have an abandonment option that can be executed so that it can be sold to another commodity firm. If the asset is highly successful, the commodity trader can continue its vertical integration upstream or downstream in the supply chain by executing an expansion option. The integration can also be done horizontally. For instance, a grain elevator located in North Dakota might fit the network well, feeding an export elevator. Further horizontal integration can be done in the area by acquiring additional country elevators to feed the export elevator. By evaluating the embedded real options, a commodity trader can find an asset's real value. However, this thesis focuses on the switching option embedded in the physical assets. The option to pay a fixed cost to shut down the elevator indefinitely is also evaluated. Besides, several projects with high initial costs that seem unworthy with traditional DCF analysis are worthwhile when future strategic options are considered (Mun, 2010).

Hereafter, the focus is on a buyer for soybeans shipping to China and how he should vertically integrate backwards into the value chain. The first step is to acquire an export elevator in one area. At this point, horizontal integration can be done by acquiring an export elevator in another area. Then, the commodity trader has the option to further vertically integrate into the country elevators. As soon as one country elevator is acquired, horizontal integration can happen by gaining control of additional country elevators. The principle would be exactly the same if the original case was a commodity-trading firm that has country elevators but seeks to integrate forward in the value chain.

The Switching Option

Consider a firm that produces multiple output with uncertain demand. The firm faces two options: it can build a plant using cheap, but rigid, capital that can only produce one good versus more flexible (and more costly) production facilities. The same principle applies to commodity traders. Instead of restraining oneself to a certain origination, a commodity trader might buy the option to use the alternative with the lowest cost.

Consider the price of soybeans across three locations; the prices are positively correlated, but have different market trends and cycles that can make one location cheaper. One can assume that soybeans across the three locations are close substitutes; therefore, the commodity trader has no preference for the location (only for the price). The commodity trader would, therefore, be willing to pay a premium for the physical assets that allow switching between these locations. Actually, the switching option becomes more valuable with a lower the inter-market correlation (Chevalier-Roignant & Trigeorgis, 2011). As an illustration, soybean prices for locations 1 and 3 have a correlation of 0.96 while prices at locations 1 and 2 have a correlation of 0.99. Then, for a commodity trader with physical assets at location 1, the switching option with location 3 has more value. This correlation, however, does not account for shipping prices to the destination and should, therefore, only be regarded as a simple illustration of how switching options get their value.

To compare the locations, the commodity trader must adjust the price (P) to transportation costs (T) (from the origin to destination) and base the decision on where to ship from using Equation 2.

$$P_b = Max\{P_1 + T_{1j}, P_2 + T_{2j}, P_3 + T_{3j}\} \quad (2)$$

P_b denotes the location with the most favorable price; therefore, the shipment would originate from there. P_i denotes the origin prices, and T_{ij} denotes the transportation price from the origin market to destination.

As soybeans across the locations are perfect substitutes, when the transportation-adjusted price ratio equals 1, the trader would have no preference about a location. Economic theory suggests that this ratio should be mean reverting since soybeans across locations are substitutes for each other. In the long run, the transportation-adjusted mean should be at a point where it is the same for marginal purchasers of soybeans (Amram & Kulatilaka, 1999). However, every short-run deviation is an arbitrage opportunity for the commodity firm with the right optionality.

To evaluate the value of this optionality, it is important to establish how often and how large the savings will be during an origination shift. If there are no switching costs, theoretically, a shift should occur any time a location is cost-minimizing. If switching costs are included, the switch would first occur when the savings exceed the switching cost (S) (Amram & Kulatilaka, 1999). If location 1 is currently used as the origination location (indicated by the subscript on C), the cost (assuming a maximum of 1 switch per week) for the next week would be as follows:

$$C_1 = \text{Min}\{P_1 + T_{1j}, P_2 + T_{2j} + S, P_3 + T_{3j} + S\} \quad (3)$$

The Correct Option Style

Before defining the application frame and valuing the actual flexibility of this real option, the correct option style must be identified. The potential switching between origination locations can occur at any point while the option is valid; therefore, the option is the American type. Because it is a switching option, it has a property that, in a sense, can be regarded as a sequence of options. Whenever it is exercised, the grain trader has another option to ship again at a later time. This continuous optionality means that the option can be exercised any day within the trading period. In other words, the commodity trader can decide to switch the origin location at any point the physical commodity is owned and in operation.

The Valuation Model

The first step to construct a valuation model is to identify some state variable. To use real-option analysis, the decision maker (manager) must be able to observe this state variable and take action, such as increase production, develop land, or suspend production, based on the variable. The state variable could, for instance, be the price of gold or the demand for cocoa. For this thesis, the state variable is the soybean price in Qingdao while the decision variable is the price at each grain elevator (i.e., the location from which to ship). It is assumed that the manager acts in a manner to maximize the market value of the existing shareholders' stake in the firm. From this goal, it is possible to show the underpinnings of real-options analysis: the manager observes the state variable (for which he has no control and which is the main source of risk for the project), and the manager takes action. This series of actions, together with the current state of the project, determines the cash flow (Guthrie, 2009).

Binomial Tree

After the state variable is defined, ROA assumes that the variable's behavior can be represented by a binomial tree. By looking at Figure 3.1, we can see the traditional way to display this information in a spreadsheet. $X(i,n)$ denotes the value of the state variable at date n if exactly i down-movements have occurred since date 0. Just as in a matrix (or spreadsheet), i also refers to the table row, and n refers to the column (that represents the date). The state variable takes the value of X at date 0; thereafter, it will take the value of either X_u or X_d at date 1. The move from X to X_u is referred to as an up move while the move from X to X_d is a down move. This pattern means that a series of two down moves would give the value of X_{dd}. The order of these moves should have no effect on the state variable. If there has been a sequence of one-up and one-down moves, the state variable takes the value of X_{ud} regardless of the order in which the moves occurred. Each of the values X can take on, has a corresponding probability (P) of occurring (displayed in Figure 3.2) (Guthrie, 2009).

Table 3.3. Representation of a Binomial Tree

X(*i*,*n*)	0	1	2
0	X	X_u	X_{uu}
1		X_d	X_{ud}
2			X_{dd}

Table 3.4. Representation of Risk-Neutral Probabilities

X(*i*,*n*)	0	1	2
0	P	P_u	P_{uu}
1		P_d	P_{ud}
2			P_{dd}

The importance for decision making comes from the risk associated with the state variable at each point. Here, the cash flow (CF), Y(*i,n*), will be generated at each node (*i,n*) of the binomial tree. For Figure 3.1, the owner receives the following CF

1. CF of Y(0, 0) at date 0 (a risk-free CF);
2. CF of Y(0, 1) or Y(1, 1) at date 1, depending on if an up or down move occurred; and
3. CF of Y(0, 2), Y(1, 2), or Y(2, 2) at date 2, depending on which value of X_{uu}, X_{ud}, and X_{dd} the state variable takes at date 2.

At date 0, the CF is risk free (because there is only one option). For the remaining two dates, the CF has a risk factor because the value of the state variable is unknown (hence more than one option) (Guthrie, 2009). The valuation model is based on the assumption that the best way to estimate the market value of a future cash flow is to use the information contained in the market.

In principle, ROA attempts to find a portfolio of traded assets that generates a cash flow close to the one being valued. Then, the cost of this portfolio is used as the market-value estimate. The reasoning behind this estimation is the belief in efficient markets (Guthrie, 2009). Here, the state variables are soybean prices in Qingdao; the decision variables are the prices at the origination locations; and the portfolio being built is the network of physical assets used for the grain trade. Moreover, it is important to point out that the binomial option-pricing model does not predict future values for the underlying assets. The assumption is that the future values follow a multiplicative binomial distribution (Lander & Pinches, 1998).

Requirements, Problems, and Warning Signs

Before applying the real-options model, it is important to understand the requirements, limitations, and potential warning signs. For an overview of the requirements needed to use real-option analysis, see Table 3.3. Without all these requirements satisfied, the analysis can assign no value and, therefore, will not add any value to the commodity trader's strategy (Mun, 2010).

Before analyzing the optionality provided by additional origination assets, one must see if the five ROA requirements are fulfilled (Mun, 2010).

1. Casavant and Griffin (1983) valued grain elevators in North Dakota. They found that elevators in the central portion of the state had slightly higher valued elevators (Casavant & Griffin, 1983). This valuation can be done with, for example, discounted cash flow analysis. Therefore, a financial model does exist.
2. Uncertainties must exist; grain traders face several risks, such as price risk, transportation price risk, and changing prices across geographical locations.
3. These uncertainties must affect the decision process; the price risk affects when grain is shipped; geographically changing prices affect where grain is shipped from; and

transportation price risk affects transportation decisions (such as the transportation method).

4. The decision maker must have flexibility for decision making; the commodity trader has flexibility for choosing transportation modes; selling strategies can be changed; and the locations the trader will ship to and from also have flexibility.
5. The commodity firm must be able to execute the options when they become the optimal strategy; the trader has the potential to execute the origination and destination options when they are optimal as well as utilizing the preferred transportation mode.

This list means that all five requirements in Table 3.3 are fulfilled in this case, and one can continue to develop the model. Before this stage, it is important to be aware of the problems and warning signs associated with real-option models.

Table 3.3. Requirements for Real-Option Analysis (Mun, 2010)

Requirement	Reasoning
A financial model must exist to value the physical asset.	ROA builds on previous DCF models and other current financial-modeling techniques. If a financial model does not exist (nor can be made), it must mean that the decision process is already complete and that no financial justification is needed.
Uncertainties must exist.	ROA is worthless unless there is an aspect of uncertainty. This lack of value stems from the value drivers behind options. If volatility is nonexistent, options have no value. If everything is known in the present, DCF analysis is sufficient.
These uncertainties must also affect the decision-making process and the results of the financial model.	The uncertainty then becomes risks which can be hedged on the downside and can be made available on the upside.
The commodity trader must have flexibility for decision making.	If there are no options to handle this uncertainty, or no flexibility for decision making to address this uncertainty, ROA has no value.
The commodity firm must also be able to execute the options when they become the optimal strategic movement.	Options are worthless if they are not executed appropriately.

Criticism and Problems Related to Real Options

Real options create a powerful modeling framework. They allow to managers to account for the flexibility to make midcourse corrections when uncertainty is resolved over time. A critique against ROA has been the claim that it overestimates the project's value. However, this critique is false as long as all five requirements for real-option analysis are actually fulfilled by the project's attributes. A further critique on the inflated value is the fact that options always have a value above zero. The latter is indeed true. The solution is also very simple; just because the option has a value does not mean the overall strategy has a positive value. The cost of obtaining the option must not be ignored. For example, a power plant can retrofit its turbines to run on both oil and natural gas (i.e., creating a switching option). If one assumes that this option is worth \$1 million, the option has value. The overall project can still be worthless if, for example, the retrofitting costs \$2 million (Mun, 2010).

Previous Studies Using the Flexibility to Switch

Electrical power plants have two major real options that are useful for this thesis. The first is the role as a call option for the spark spread. The spark spread is the theoretical gross margin of a gas-fired power plant selling one unit of electricity, accounting for the cost of the fuel needed to produce this unit of electricity. This spread must cover all costs for operating the power plant. The payoff from this option is as follows:

$$R = \max\{PP - HR \times FP, 0\}, \tag{4}$$

where R represents revenue, PP denotes power price, HR represents heat rate, and FP denotes fuel price. The formula has a simple interpretation for the power-plant management. If the spark spread is positive (accounting for all operating costs), produce. If the spark spread is negative, do not produce (de Jong, 2008).

The de Jong (2008) article shows the revenue generated by a call option on the spark spread. Similarly, a grain elevator can be seen as a call option for shipping grain from the location when the market is beneficial. Siclari and Castellacci (2005) take this model a step further by modeling it as a power plant that consists of generators that can run on different fuels. They model this relationship as a basket switching-option. The payoff can be viewed as the spread between the price for power and the minimum for two baskets of stochastic cost factors. These cost factors could, for example, be emission and the prices of different fuel types. Adjusting the payoff for the flexibility provided by a generator that can run on three different fuels (denoted by subscripts 1, 2, and 3), the option's payoff then becomes

$$R = \max\{PP - \min\{HR_1 \times FP_1, HR_2 \times FP_2, HR_3 \times FP_3\}, 0\} \tag{5}$$

Siclari and Castellacci (2005) show that one of the essential factors in modeling these types of switching options is to get the variance and the correlation of the variables right. Their work shows that the spark-spread option can be supplemented by an option that allows the power plant to select the cheapest input fuel (Siclari & Castellacci, 2005). Allowing the power plant to switch fuels is conceptually similar to changing the location for soybean origination. The electricity price is substituted with the destination price for the grains; the fuel price is substituted for the cost of the grain, including transportation costs, at the origin.

Adkins and Paxson (2011) model facility flexibility and the impact of switching costs. They find that switching between an open and a closed production facility is lagged when switching costs are present. The switch must produce enough profit to offset the switching costs. The study finds that the flexible facilities have a substantially higher value than the NPV of the present production. The value of a flexible facility is the option value for the flexible asset plus the value of current production. The model further shows that input correlations and volatilities drive the option's value (Adkins & Paxson, 2011).

Representing Commodity Prices

The Geometric Brownian Motion stochastic process model is the most common modeling structure for real options. This model might be a problem when representing commodity prices because they generally have mean reverting attributes. If the commodity is mean reverting, the Geometric Brownian Motion Models tend to overestimate the project's value. The logic behind mean-reverting models stems from economic theory. When prices are high, demand for the product tends to decrease as consumers substitute towards other goods. Simultaneously, the high prices trigger new entrants to the market. These factors eventually force the price towards the long-term mean. Commodity markets are considered to exhibit this behavior and will, therefore, generally be better suited with a mean-reverting model (Pinto, Brandao, & Hahn, 2007)

Flexibility and Contracting

For flexibility to have a value, there must be something you want to avoid. If there are never any adverse events, the flexibility to avoid them has no value. Conceptually, the same would be the case for an option. If there is a zero likelihood that the option will be exercised, it should not have any value. Grain traders managing physical assets can cease their elevators' operation (pay a shutdown fee) or keep them running without shipping (only incur fixed running costs, with no losses from shipping). This complete flexibility to operate the elevator optimally renders the option to switch locations worthless. Each elevator will ship whenever profitable and not ship whenever unprofitable. This behavior leads to no switching, only independently operating facilities reacting to all market moves. If there would be an inefficiency or a barrier for this optimal behavior, the flexibility to alternate origins receives a value.

Assume that a grain trader can only buy grain from one of two origins and that the trader has a certain demand to meet. The obligation to meet this demand can be imposed on a trader by contracting. In this thesis, contracting is defined as any agreement between the trader and a purchaser which forces the trader to deliver grain to the destination market at the destination price regardless of the market conditions. If the trader can only procure grain from the two locations, losses will arise whenever both markets are above the destination's market price. In that case, the commodity trader can originate all the grain needed to fulfill all obligations at the most attractive price. If each of the markets were operated by independent traders, both of them would incur a loss. (The one with the worst market incurs the largest loss.) If the markets had managed their assets together, this loss would have been avoided, and both traders could have honored their contracts with the best market price.

Switching options gain their value by providing flexibility; then, a switching option must also lose value when flexibility is removed. The model identifies this excessive contracting threshold where the switching option starts to decrease in value. Just as the flexibility is worthless in a perfectly managed scenario, with a scenario where all capacity is contracted, the switching option cannot provide any value because there is no free capacity to divert to the most favorable market. The switching option essentially provides flexibility when imperfections arise; therefore, as long as the switching option provides greater flexibility than the imperfection imposes, the value of the network stays the same. This maximum point of imperfection without any effect on net present value is defined as the optimal contracting threshold. If contracting creates value for the trader, all traders should contract the amount (and accept the lack of flexibility) as long as their flexibility at the origination can compensate for the reduced flexibility from contracting

Conclusion

From the theory related to real options, one can find a feasible basis for the model. The option is modeled as a switching option. The option type is a call on the spatial-arbitrage opportunities. The destination price should be mean reverting because this property is exhibited by several commodities (Pinto, Brandao, & Hahn, 2007). The profit opportunities come from the correlations and volatility in the spread between the different origins and the final destination (Adkins & Paxson, 2011).

CHAPTER 4. EMPIRICAL MODEL

Introduction

This chapter develops an empirical model to value the net present value of cash flows facing a commodity trader based on the embedded flexibility in his origination network. The network in question supplies the Chinese market (Qingdao) with soybeans from the Pacific Northwest (PNW), the U.S. Gulf (USG), Brazil (Paranaguá), and the Ukraine's Black Sea region (Black Sea). Having physical assets spread over these regions provides the ability to export from multiple origins. The ability to change the export location gives the trader the optionality to take advantage of temporarily attractive prices. The model is developed to value this advantage, also referred to as the value of the switching option. Each port origin, again, has the optionality to procure soybeans from country elevators spread across the respective regions (Ukraine excluded). This two-step integration divides the model into two major blocks: first, the cash flow received from purchasing soybeans track at the export elevators and then shipping them to Qingdao to be delivered Freight On Board (FOB; i.e., delivered at the harbor but still located onboard the ocean vessel). Second, the cash flow received by purchasing grain at the country elevator level and then shipping it to the export elevator (delivered track). Both values represent the net present value for the estimated cash flow over the next 10 years.

Each steps is modeled in two scenarios; first, the model values each grain elevator as a standalone asset (no switching), and second, the model values the elevator as part of a network that allows for switching (input switching for the network). To define the model, the chapter first describes (1) Modeling the Destination Market Price, (2) all inputs to model the origin market, (3) the valuation method for individual elevators, (4) the valuation method for a network with switching, and (5) the valuation of the switching option relative to contract obligations (as a percentage of the total yearly capacity).

The model accounts for the cost and profits associated with operating the elevator (fixed costs and variable profits). To model this behavior, one first needs to recognize that the model must keep track of the destination prices, the profits incurred by shipping, and the probabilities of this profit occurring. The most important concept for valuing the flexibility provided by this switching option is the concept of contracting. Contracting is defined as follows: in some way (usually by contractual obligations), the commodity trader has committed to deliver a certain amount of a given commodity at the destination market for the price currently being quoted there. Assuming, the commodity has a chance of incurring losses due to this contracting behavior, the trader essentially introduces an inefficiency into his network of physical assets. Commodity traders might be willing to accept this inefficiency as long as the written contract provides some utility exceeding the inefficiency (and, therefore, decreased cash flow). Contracting's effects on the switching option (as discussed in Chapter 3) are accounted for by separate binomial trees that keep track of the contracted amount's value (no switching), the value of the leftover capacity (after the contracted amount is shipped) if the elevator is shipping, and when the elevator is not shipping. Finally, the model must keep track of the contracted amount assuming that switching is allowed.

Modeling the Destination Market Price

To represent the destination market, the model estimates a binomial tree for soybean prices at the destination. The current destination price is denoted as X. The binomial tree changes either up or down in accordance with the average monthly price change for soybeans which is denoted by Δ.

Up moves are calculated by:

$$X_u = X \times (1 + \Delta) \tag{6}$$

Down moves are calculated by:

$$X_d = X \times (1 - \Delta) \tag{7}$$

After 120 months of consecutive up moves, soybean prices would reach $52,913 per bushel. As previously stated by Pinto, Brandao, and Hahn (2007), many commodities exhibit a mean-reverting pattern, the model must account for it, and probabilities for up and down moves must be assigned. By running a batch fit for historical soybean prices at the destination (2004-2013), one can see that Qingdao's soybean prices are best represented by a triangular distribution (11.75, 15.35, 21.08) representing the minimum, most likely, and maximum values in dollars/bushel. See Figure 4.1.

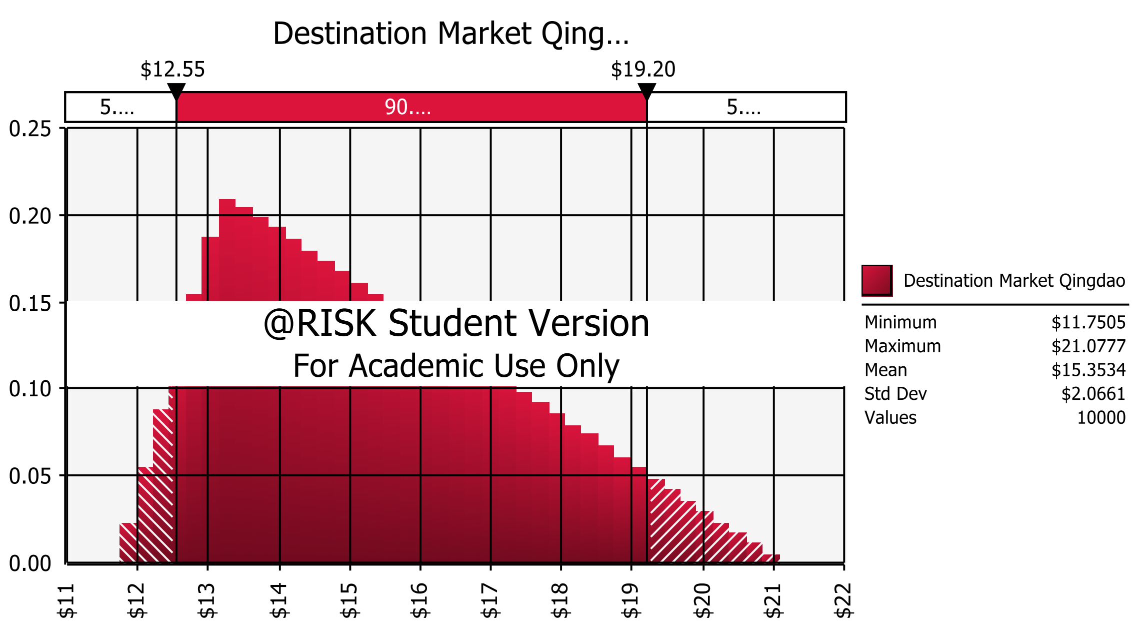

Figure 4.1. Distribution of Soybean Prices, Qingdao

The probability for the next move to be up is then calculated using @Risk's "RiskTarget" formula which provides the cumulative probability of a given target value in the simulated distribution (i.e., the probability of a value that is less than or equal to the target) and is denoted by P_c. The probability for the next move in the binomial tree to be up (denoted by P_u) is then

$$P_u = 1 - P_c \tag{8}$$

The probabilities for down moves (denoted by P_d) are subsequently

$$P_d = P_c \tag{9}$$

The probability of an up move is displayed in a binomial tree shape (in accordance with the price tree). When the probabilities of an up move approach zero, the next price move must be down (indicated by the red color). With the probabilities of an up move approaching one, the next price move must be up (indicated by the green color). The price of soybeans is, as a result, most likely to be in the middle area (marked in yellow) of the probability lattice. See Figure 4.2.

0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.05	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.15	0.10	0.06	0.02	0.00	0.00	0.00	0.00	0.00
0.27	0.21	0.15	0.10	0.06	0.03	0.01	0.00	0.00
0.41	0.34	0.28	0.22	0.16	0.11	0.06	0.03	0.01
0.55	0.48	0.42	0.35	0.28	0.22	0.16	0.11	0.07
0.69	0.63	0.56	0.49	0.42	0.35	0.29	0.23	0.17
0.83	0.76	0.70	0.63	0.56	0.49	0.43	0.36	0.29
0.96	0.90	0.83	0.77	0.70	0.64	0.57	0.50	0.43
1.00	1.00	0.96	0.90	0.84	0.77	0.71	0.64	0.57
	1.00	1.00	1.00	0.96	0.90	0.84	0.78	0.71
		1.00	1.00	1.00	1.00	0.97	0.91	0.85
			1.00	1.00	1.00	1.00	1.00	0.97
				1.00	1.00	1.00	1.00	1.00
					1.00	1.00	1.00	1.00
						1.00	1.00	1.00
							1.00	1.00
								1.00

Figure 4.2. Probability of Next Move to be Up (Outtake)

Modeling Profit for Individual Origin Markets

To model each elevator, one first needs to define the main value drivers. Intuitively, the value driver is the profit potential. The profit potential is determined by correlations and volatility for transportation costs (Pinto, Brandao, & Hahn, 2007) as well as the spread between the origin and the final destination (Adkins & Paxson, 2011). Logically, the value behind the switching option comes from price differences across locations. Because the seasonal profit opportunities vary across locations, traders with a well-diversified network have the optionality to fulfill their contracted capacities from the market with the best conditions (highest potential for spatial arbitrage). The profit opportunity for an elevator is defined in Equation 10 and denoted by π.

$$\pi_{ij} = X - (T_{ij} + X_i), \tag{10}$$

where X denotes the price at the destination market and X_i equals the price at the origin in question.

To create a realistic representation, the model must adjust for seasonal differences. In addition to the potential to capture arbitrage profits during grey- and black-swan events, the day-to-day driver of value might be differences in seasonal prices. If the Ukraine, Brazil, and the United States have different time periods where prices are seasonally depressed, the model captures this seasonality by using seasonal indexes as input costs (based on historical data).

The historical (2008-2013) average profit opportunity (π) is used to create seasonal indexes (by month). The average and standard deviation for profit opportunities by month are identified. As an example, the seasonal profits and standard deviations for all export elevators are graphically represented in Figure 4.3. Figures 4.4 and 4.5 display the data for select country elevators that ship to Paranaguá and USG, respectively.

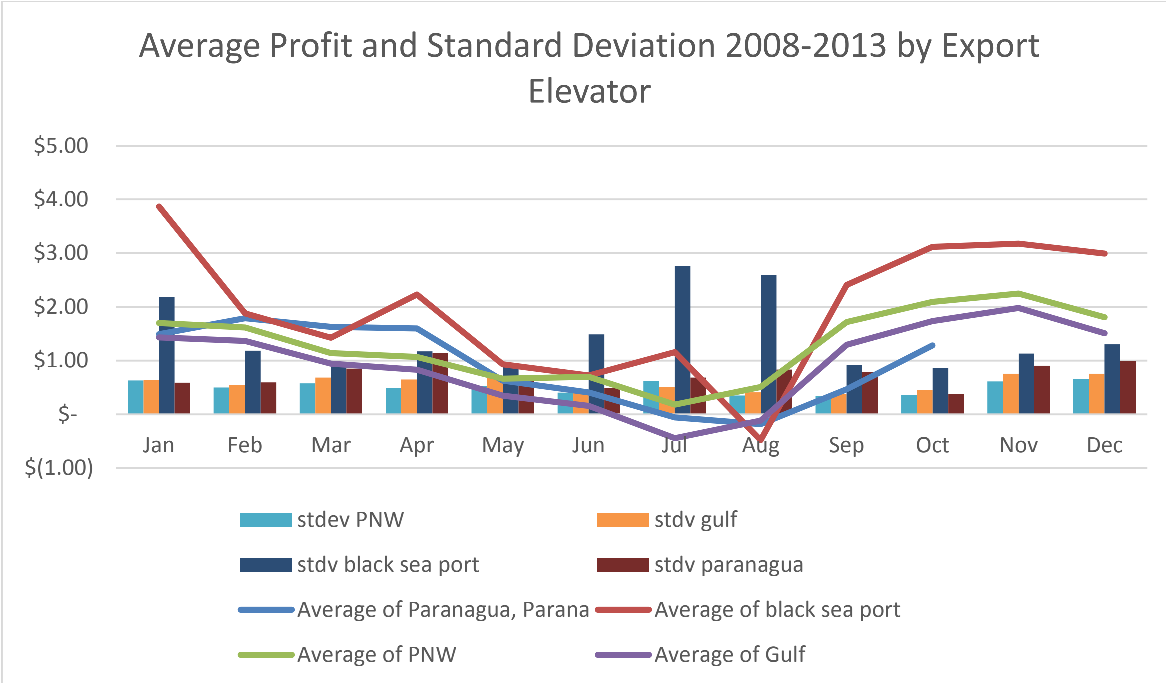

Figure 4.3. Seasonal Profit Opportunity for the Export Elevators

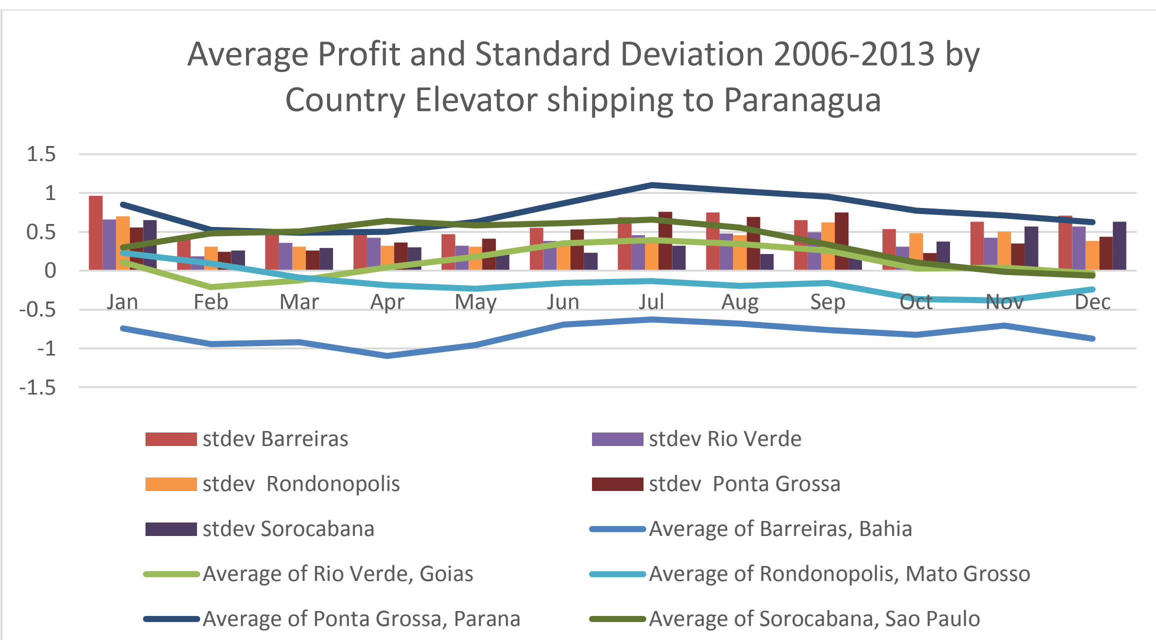

Figure 4.4. Seasonal Profit Opportunity for the Country Elevators Shipping to Paranaguá

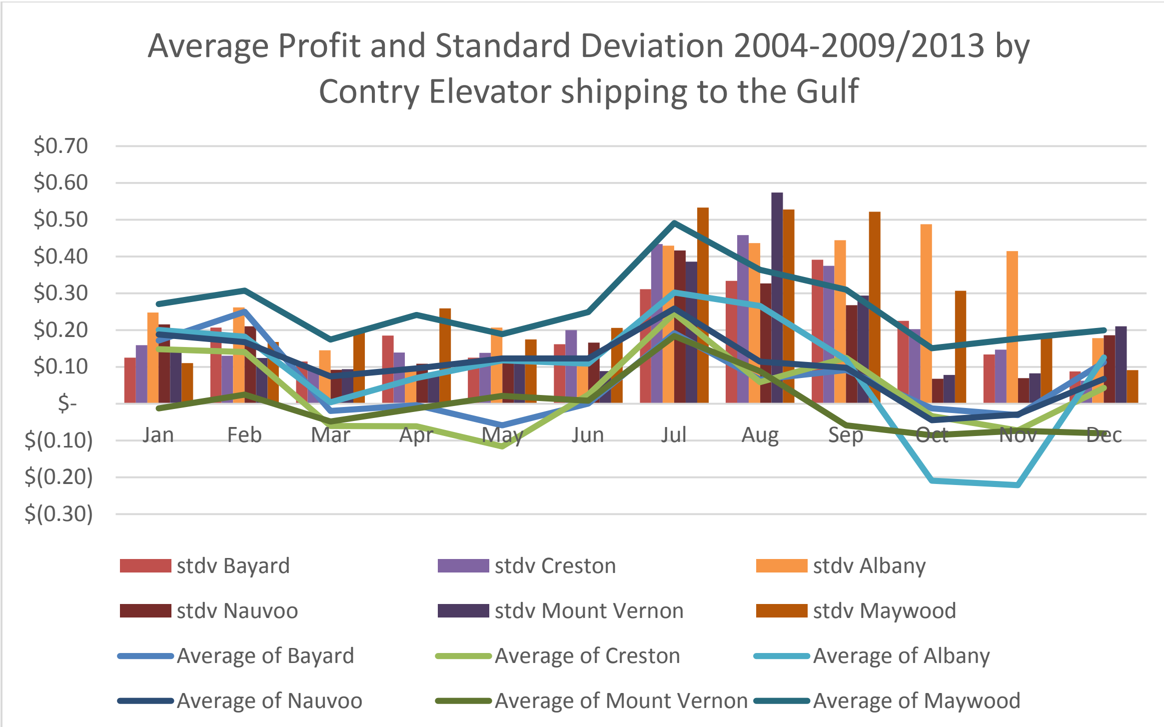

Figure 4.5. Seasonal Profit Opportunity for the Country Elevators Shipping to USG

These seasonal indexes are then converted to stochastic variables that are represented by a normal distribution. A normal distribution was selected based on the Akaike Information Criterion. Each stochastic variable is correlated in accordance with the correlation tables displayed in the Appendix. The correlation ensures that profit opportunities accurately mimic the actual market behavior. If one market increases in profitability or another decreases, the correlation between the stochastic variables ensures no overestimation in profitability. Table A1 displays the correlations for export elevators. Table A2 the displays correlations for country elevators shipping to the U.S. Gulf. Table A3 displays the correlations for country elevators shipping to the U.S. Gulf when allowing the Jasper, Ayr, Finley, Jamestown, Beatrice, Dorchester, and Edison elevators to ship to the Pacific Northwest, if favorable. Table A4 displays the correlations for country elevators shipping to Paranaguá.

Appendix Tables A5-A8 display the same correlation tables but for market price only; therefore, no adjustment for shipping cost is considered. The correlations for profit opportunities are far lower than the correlations for market price. For example, the average correlation of profit opportunities for the elevators based in the United States, when only shipping to the Gulf, is 0.78 (and 0.77 when shipping to the PNW as well) while the correlations between the respective market prices are 0.9962, or nearly perfect correlations. The Brazilian market shipping to Paranaguá displays this property even stronger; profit opportunities are, on average, correlated a mere 0.62 while market prices for the same locations are correlated by 0.9887. The export elevators shipping to Qingdao have profit opportunities correlated by 0.61 and market prices correlated by 0.75, on average.

Profit from Vertical Integration

The model compares networks with and without the ability to switch the origin. This comparison can be seen as a network of independently owned and operated elevators (not cooperating) versus a network that is owned and operated by a commodity-trading firm (which, therefore, has the optionality to switch origins). Conceptually, vertical integration would be what the commodity-trading firm accomplishes by acquiring an elevator at another stage in the value chain. Because all outputs from the network go to the Chinese market, a vertically integrated trader would own physical assets at each step in the value chain until the origin market is reached. Traders that seek vertical integration would, in this case, purchase export elevators at the first stage and then country elevators as the second step (or vice versa). This complete integration would allow the trader to control parts of the flow from the origin market towards the destination market.

Modeling the Individual Elevator Value

To model the elevators' option values, the first step is to define the different operating states in which an elevator can be. The states considered in this model are (1) operating and shipping, (2) operating and not shipping, and (3) closed. This thesis does not consider sold as a state. (A sold elevator simply changes ownership; it will still be in one of the defined states). The three states are shown in Table 4.1.

Table 4.1. Elevator Operating States

State	Implications
Operating and Shipping	The elevator is running and shipping. Fixed costs are running. A profit/loss from shipping is incurred.
Operating and not shipping	The elevator is running and ready to ship. Fixed costs are running.
Closed	The elevator is shut down due to costs exceeding profits. By entering this state, the elevator incurs a shutdown cost. By leaving the state, the elevator incurs a start cost. No fixed costs are incurred. The benefit from closing must exceed the startup/shutdown costs.

Option to Cease an Elevator's Operation

The option to close an elevator is only available in this model if the management decides not to contract any part of its capacity. This option is a flexibility that management forgoes by deciding to contract. If a commodity trader has several elevators, it could be feasible to close one of them and keep the others running to fulfill obligations. However, this optionality is outside the scope of this model (for simplicity's sake).

To value the optionality to cease (and resume) operation, the model must have three binomial trees: one to track price, one to track the value at each time period if the elevator is closed, and one to track the value if the elevator is operating at the beginning of each time period. The price lattice is the destination price tree. When the elevator is not operating, the owners can either do nothing and earn zero, or open the elevator which incurs a startup cost and a fixed cost. This action gives the opportunity to ship soybeans from the location. If the elevator is operating at the beginning of the time period, management has three choices: not to ship and to incur the fixed cost of operating, or to incur the fixed cost and to receive profits from shipping (given the market conditions allow this profit), or to pay the shutdown cost and close the elevator

The model values the elevator for a 10-year period with monthly time intervals. To calculate the value of an option to close an elevator, one first needs a binomial tree to track the value at each time period if the elevator is not operating (Equation 11):

$$V_c = Max\Big(\big(X - (X - \pi)\big) \times C - SUC - FC + df\big(P_u \times V_{u,o} + P_d \times V_{d,o}\big), df\big(P_u \times V_{u,c} + P_d \times V_{d,c}\big)\Big), \tag{11}$$

where V_c denotes the value of an elevator that is not in operation, C denotes capacity, SUC denotes the cost of resuming operations, FC denotes the fixed cost of operating, and $V_{u,o}$ and $V_{d,o}$ represent the value of potential up and down moves when the elevator resumes operation. $V_{u,c}$ and $V_{d,c}$ represent the value of up and down moves if the elevator continues to stay closed. The equation calculates the current profit plus the present value (df represents the discount factor) of the expected value in the next period (given an up or down move). It is important to point out that each equation (Equations 11, 12, 13, 15, 16, 18, and 19) exists in the same form at each node in the binomial tree (regardless of the time period, and the number of up and down moves).

The second binomial tree needs to keep track of the value at each time interval if the elevator is operating with the following equation (where V_o denotes the value of the elevator if it is currently open and SDC denotes the shutdown cost):

$$V_o = Max\Big(\big(X - (X - \pi)\big) \times C - FC + df\big(P_u \times V_{u,o} + P_d \times V_{d,o}\big), -FC + df\big(P_u \times V_{u,o} + P_d \times V_{d,o}\big), -SDC + df(\big(P_u \times V_{u,c} + P_d \times V_{d,c}\big)\Big) \tag{12}$$

By using backwards induction, the value of an elevator at time 0 both in the operating and closed states. By subtracting Equation 12 from Equation 11, you obtain the difference in value for an elevator that is currently being operated or not. This subtraction can tell a potential buyer the value difference for an elevator being sold with all workers remaining at their jobs (i.e., Operation can continue uninterrupted with no startup costs.) and an elevator that is shut down where the new owners would have to incur startup costs (such as employee training and recruiting costs).

The value of the flexibility provided by the option to close the elevator is not considered in this difference. To value the option to cease operations, an additional binomial tree is needed to value an elevator that can only be operating and not shipping, or operating and shipping (Table 4.1). This level of flexibility is valued by Equation 13:

$$V_{x,c} = Max\Big(\big(X - (X - \pi)\big) \times C - FC + df\big(P_u \times V_{u,o} + P_d \times V_{d,o}\big), -FC + df\big(P_u \times V_{u,o} + P_d \times V_{d,o}\big)\Big), \tag{13}$$

where $V_{x,c}$ denotes the value of an elevator with no flexibility to cease operations. One assumes that a commodity trader prefers to acquire the elevator in either an operating or non-operating state, depending on the highest present value. One can get the option value of the flexibility to shut down production (and resume), whenever profitable, by using equation 14:

$$V_{O,c} = Max(V_c, V_o) - V_{n,c}, \tag{14}$$

where $V_{o,c}$ denotes the value of an option to cease operation.

Value of Contracting at Individual Elevators

Commodity traders will, in many cases, have the option to contract parts of their expected volumes. Reasons for contracting can include (but are not limited to) the following: the commodity trader receives a premium for guaranteeing an input; the commodity trader values secure volumes; or the commodity-trading firm also operates production facilities that must procure inputs. By contracting, the commodity trader essentially gives up the flexibility to cease elevator operations (as discussed earlier) because a stated volume now must be delivered regardless of profitability.

The value of an elevator that contracts a part of its total capacity is one of the fundamental building blocks for valuing the optionality to change geographical origination areas. Contracting elevators receive their value from two factors: (1) the value of the contracted capacity and (2) the value of the free capacity (contracted capacity subtracted from the total capacity). Contracted capacity is denoted by Z. Again, additional binomial trees are needed to keep track of each value: (1) the contracted capacity, V_z (Equation 15), and (2) the value of free capacity denoted by V_{1-z} (Equation 16).

$$V_z = \left(\left(X - (X - \pi)\right) \times Z + df(P_u \times V_u + P_d \times V_d)\right) \tag{15}$$

Notice that the fixed cost is not a part of Equation 15, as the fixed cost is considered in every time period regardless of the shipping behavior from Equation 16.

$$V_{1-z} = Max\left(\left(X - (X - \pi)\right) \times (C - Z) - FC + df(P_u \times V_u + P_d \times V_d), -FC + df(P_u \times V_u + P_d \times V_d)\right) \tag{16}$$

The value of an elevator that engages in no switching between geographical origins has the value of Equation 15 added to Equation 16. The value of the free capacity can still be negative because the fixed cost of running the elevator is incurred here.

Modeling the Elevator's Network Value

This model values the elevators as part of a network of physical assets. The network has an embedded switching option, the option to alternate origins to those origins with favorable market conditions. To value this optionality, one initially uses Equations 15 and 16 to find the value of every elevator in the network. Individually, these elevators do not engage in a switching behavior. This value is simply calculated for every elevator in the network and then aggregated (according to Equation 17), where $V_{n,r}$ denotes the value of a network with no flexibility.

$$V_{n,r} = V_{Z_1} + V_{1-Z_1} + V_{Z_2} + V_{1-Z_2} + V_{Z_3} + V_{1-Z_{13}} + \cdots + V_{Z_i} + V_{1-Z_i} \tag{17}$$

The value of the contracted amount must be valued for a network of elevators exploiting the optionality embedded in their networks. This valuation is done by applying Equation 18 to the elevators needed to fulfill the contracted amount. Managers acting in their company's best interest want to maximize profits or minimize losses. Therefore, the logical behavior would be to use elevators with the most suitable market conditions to fulfill the contracted amount.

As an illustration, if the commodity trader has 15 elevators which each have 2 million bushels of capacity per month, the commodity firm will have 30 million bushels of capacity available per month. Let one assume that the commodity firm decides to contract 33% of this capacity. In the previous case, where the optionality to change the origin is not exploited, the management will procure 666,667 bushels from each elevator, regardless of the market conditions, and then procure the free capacity only if they can receive a profit. In an unfavorable market where some elevators lose money, this management strategy is perceptibly an illogical decision. Management should rather procure 2 million bushels from the 5 elevators with the most favorable market conditions. If more than these 5 elevators can make a profit by shipping, these elevators will also ship their full capacity. Any commodity firm that does not account for this optionality will ultimately misprice the physical asset if the elevator is part of a network. Equation 18 is, therefore, applied to the elevators in a position to receive the largest arbitrage profits by shipping to the destination market and thereby fulfilling all obligations from contracting. Fixed costs are, again, only accounted for in the free capacity.

$$V_{n,Z} = \big(X - (X - \pi_1)\big) \times Z_{a,1} + \big(X - (X - \pi_2)\big) \times Z_{a,2} + \big(X - (X - \pi_3)\big) \times Z_{a,3} + \cdots + \big(X - (X - \pi_i)\big) \times Z_{a,i} + df(P_u \times V_u + P_d \times V_d), \tag{18}$$

where $V_{n.Z}$ denotes the network value of contracted capacity and Z_a denotes part of the capacity contracted carried by each elevator. Equation 19 is used to account for the fixed costs accrued by operating the elevators, and additional elevators with geographical arbitrage opportunities and free capacity (in addition to the locations used to fulfill contract obligations in Equation 18).

$$V_{n,1-Z} = \big(X - (X - \pi_1)\big) \times (1 - Z_{a,1}) + \big(X - (X - \pi_2)\big) \times (1 - Z_{a,2}) + \big(X - (X - \pi_3)\big) \times (1 - Z_{a,3}) + \cdots + \big(X - (X - \pi_i)\big) \times (1 - Z_{a,i}) - (FC \times QE + df(P_u \times V_u + P_d \times V_d), \tag{19}$$

where QE denotes the number of elevators in the network and $V_{n,1-Z}$ denotes the value of the network's free capacity. To calculate the total value of the network with the optionality ($V_{n,s}$) to switch, one simply aggregates Equations 18 and 19 in accordance with Equation 20.

$$V_{n,s} = V_{n.Z} + V_{n,1-Z} \tag{20}$$

Option to Switch Origin

The option to switch origin only has a value if imperfect management of the physical asset is imposed (as discussed earlier). The reasoning behind this lack of value is very simple. If all locations are operated perfectly (defined as no contracting), each manager will simply not ship if there is no profit, and whenever there is a profit opportunity, the trader will ship the maximum quantity. If the commodity trader has decided to contract, this flexibility is no longer available. In that case, the flexibility not to ship is removed. By utilizing the optionality to switch origin locations within a network, the trader can ship the contracted amount from locations with the best price. This switching behavior creates the switching option's value.

Assume that ten traders each operate one location (and are contracting a part of capacity). They can never exploit this option because each trader only controls one origin. By working together, they can exploit this option. By managing the elevators as a network, the value of the switching option is captured. As a result, the whole is greater than the sum of the individual parts. Each trader is now reaping higher profits. The actual value of the switching option is found with Equation 21:

$$V_{o,s} = V_{n,s} - V_{n,r} \tag{21}$$

The Optimal Amount to Contract

The optimal amount to contract is obviously subjective, however, if we assume that contracting provides some value to a commodity trading firm, either through guaranteed quantities or price premiums, every commodity manager should want to contract the maximum amount possible without reducing the value of his trading network. Equation 12 calculates the value of an elevator that cannot close. If Equation 12 is aggregated for each elevator in the network, the result essentially gives the value of a network that neither has the flexibility to shut down nor to contract any of its capacity (denoted by $V_{n,Z=0}$) (Equation 22).

$$V_{n,Z=0} = V_{x,c_1} + V_{x,c_2} + V_{x,c_3} + \cdots + V_{x,c_i} \tag{22}$$

When grain traders decide to not contract any of their total capacity, a network of the same elevators will have the same value regardless of the ability to switch geographical locations. In other words, Equation 23 is true with no contracting.

$$V_{n,Z=0} = V_{n,s} = V_{n,r} \tag{23}$$

This equal value for the networks stems from the fact that the switching option has no value under perfect management (i.e., no contracting). However, if a commodity firm manages a network that has the option to switch locations and receives value (in some form) from contracting, the trader should contract the maximum percentage of the total capacity that does not decrease the network's value. (i.e., Equation 24 still holds true.) If management decides not to contract, if contracting provides a benefit, and if the traders could have contracted a part of total capacity without reducing the value of the network, the management essentially foregoes a "free" benefit provided by contracting.

$$V_{n,s} - V_{n,Z=0} = 0 \tag{24}$$

Note that the value in Equation 24 can never be positive. It can only be zero or negative. This property holds true because the switching option has no value if nothing is contracted, and the optionality can, therefore, never raise the value of the network above the no-contracting condition. The option to switch can only raise the value compared to a network that does contract but has no option to switch. If the value is less than zero, the commodity trader is contracting an amount so large that the flexibility provided by the switching option is smaller than the inflexibility created by contracting (and, therefore, reducing the value of the flexibility). Intuitively, a commodity firm contacting 100% of its capacity cannot switch between locations; there is no room for adjustment.

Data Sources

All data in the models were collected for the time period between January 1, 2004, and August 1, 2013. Different locations and shipping routes had missing prices for certain time periods, and the seasonal indexes were, in that case, based upon a shorter time period. (The shortest data series used was 5 years.) All soybean prices across the United States, Brazil, and the Ukraine (excluding the PNW and USG export elevator prices) were collected from Bloomberg Terminals (Bloomberg, 2013). Track and FOB prices at the USG and PNW export elevators were provided by Trade West Brokerage Co. Barge tariff rates for the Mississippi River were collected through the United States Department of Agriculture's Agricultural Marketing Service (AMS). Ocean freight rates from Brazil to China were collected from AMS. Truck transportation rates in Brazil were collected through AMS and private sources. Ocean freight rates from the U.S. locations were derived from the ocean freight rates to Japan (AMS) in the same time period. Ocean freight rates from the Ukraine to China were based on AMS shipping quotes from the Ukraine to the Netherlands and to South Africa, and were adjusted in accordance with distance and market trends in the grain-shipping industry (aggregate of the other transportation costs). Rail transportation rates for the United States were provided by Wilson and Dahl (2011) and gathered from Burlington Northern Santa Fe (BNSF). These data included tariffs, fuel-service surcharges, and shuttle premiums (but are for 2004-2009 only) (Wilson & Dahl, 2011). All data were converted to spatial-arbitrage profit opportunities by month and, thereafter, converted to seasonal indexes for spatial-arbitrage profit opportunities. (See the section on seasonal price indicators and distributions).

The startup, shutdown, and fixed costs are assumed to be constant throughout time. These costs are based on Wilson and McGree's article (Wilson & McGree, Risk and return trade-offs in partnering strategies between co-ops and IOFs, 2013). All opperating costs and capacities for each elevator type are listed in Table 4.2 for the export elevators and Table 4.3 for the country elevators. The discount rate is held constant at 6%, except for one sensitivity analysis with increasing rates.

Table 4.2. Operating Costs for Export Elevators

Factor	Symbol	Assumption
Monthly Capacity in Bushels	C	10 million
Monthly Fixed Cost	FC	$1 million
Startup Cost	SUC	$10 million
Shutdown Cost	SDC	$10 million

Table 4.3. Operating Costs for Country Elevators

Factor	Symbol	Assumption
Monthly Capacity in Bushels	C	2 million
Monthly Fixed Cost	FC	$215 thousand
Startup Cost	SUC	$1 million
Shutdown Cost	SDC	$1 million

Seasonal Price Indicators and Distributions

The profitability for each elevator (country or export) and its respective destination market (export elevator or Qingdao) was calculated in accordance with Equation 10. Each market's geographical locations are represented in Figure 4.6. The black lines extending from the export elevators represent the areas where the country elevators shipping to these are located.

The profitability data for each location are then converted into distributions based on the average and standard deviation by month. Each month is represented by a normal distribution. These data make up all random variables in the model and are displayed in Table A9 for export elevators shipping to Qingdao, A10 for country elevators shipping to USG, A11 for country elevators shipping to both PNW and USG, and A12 for country elevators shipping to Paranaguá.

Correlations between the random variables are displayed in Table A1-A4, respectively. Figure 4.7 displays the historical profit opportunities of select country elevators in Brazil to illustrate the properties upon which the random variables are based.

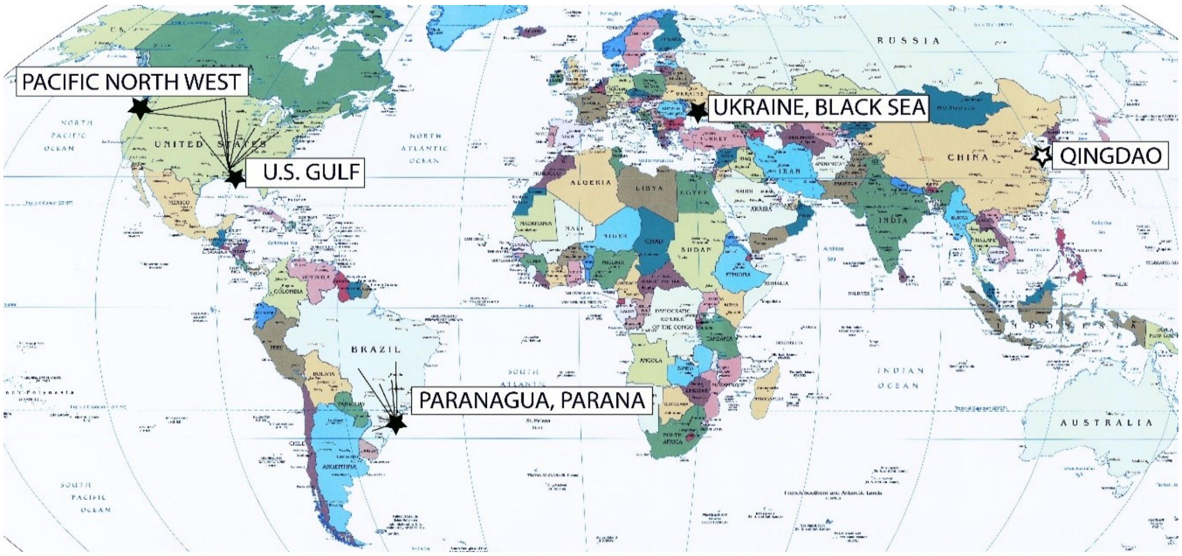

Figure 4.6. Geographical Locations for the Origin Markets and the Destination Market

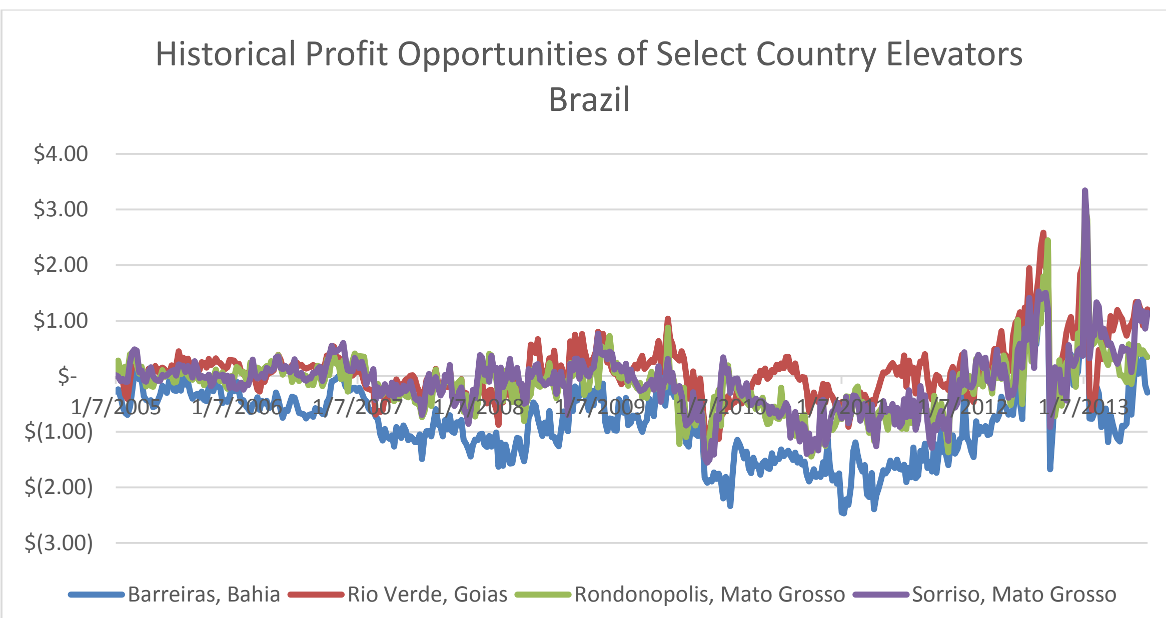

Figure 4.7. Historical Profit Opportunities for Select Country Elevators

Simulation and Optimization Procedures

The model is simulated first with a base case. The base case values the optionality to participate in spatial arbitrage between the export elevators and the destination market. Thereafter, sensitivities (contracting levels, correlations, profit distributions, and discount rates) are changed to illustrate the value drivers of the switching option. The switching option's impact on total NPV is discussed in relation to changing distributions and correlations. Sensitivities for contracting levels have been further tested on country elevators that ship to Paranaguá to illustrate the impact on NPV as well as the concept of the optimal and excessive contracting levels. Elevators supplying the PNW and USG export elevators are modeled to illustrate the different cash flows created by individual elevators. The acquisition of an additional export elevator by a pre-existing network of country elevators is modeled. Finally, the PNW elevators are used to illustrate the value of the option to cease operation and how it is related to the profit distributions. These sensitivities have been simulated in Palisade's @Risk software, with 10,000 trials, to find the switching option's value and the percentage of the total network value for which this switching option accounts.

The model assumes that the discount rate, the fixed costs, the startup costs, and the shutdown costs are static and remain the same for the entire time period. Random stochastic variables consist of each elevator's seasonal profitability opportunities.

Illustrative Example

As the model analyzes several elevators over 10 years, the binomial trees become large, and each tree has thousands of nodes. Therefore, the exact decision process becomes harder to follow. To make this process clearer, this section features an example that covers two elevators over two time periods. Because the goal is to highlight the decision process, several simplifications have been made: (1) the startup, shutdown, and fixed costs are set to zero; (2) the seasonality of each elevator is not a stochastic, random variable but is a fixed value; (3) the destination's market price is set at $10/bushel regardless of the up and down moves; (4) the probabilities of up and down moves are constant at 0.5; (5) the discount rate is set to zero; and (6) the amount of total capacity contracted is 50%. These simplifications do not change the decision process. All assumptions are listed in Tables 4.4 and 4.5.

Table 4.4. Assumptions for the Illustrative Example

Factor	Symbol	Assumption	Corresponding Equation
Soybean price at destination	X	10	
Probability of an up move	P_u	0.5	8
Probability of a down move	P_d	0.5	9
Contracted capacity/elevator	Z	50	
Capacity/elevator	C	100	
Discount factor	df	0	

Table 4.5. Seasonality Assumptions for the Illustrative Example

Elevator	Symbol	t_0	t_1	t_2	Corresponding Equation
Profit Elevator 1	π_1	0	1	-0.25	10
Profit Elevator 2	π_2	0	-0.25	1	10

To illustrate the value of the switching option, Equations 15 and 16 are first applied to the above-listed assumptions. This application gives the value of each elevator's contacted and free capacities. Looking at Table 4.4, one can clearly see that neither elevator has any potential for spatial arbitrage at t_0. At t_1, Elevator 1 has a $1 profit from spatial arbitrage while Elevator 2 loses $0.25 per unit shipped. At t_2, the profits for each elevator are flipped. Figure 4.8 applies Equation 15 to Elevator 2 and finds that Elevator 2's value of the contracted capacity is $37.5. The value of the free capacity is found in Figure 4.9 by using Equation 16 and is $50. Because the discount rate is equal to 0, Elevator 1 has the same NPV, and Equation 17 gives the network of independently operated elevators (i.e., no switching option) an NPV of $175.

If there were a discount rate in the example, Elevator 1 would have a higher value than Elevator 2 because the spatial-arbitrage profits are discounted at each node in the binomial tree. Table 4.5 shows that Elevator 2 receives its $1/unit profit at a later node in the tree. If each node is a 1-month interval, a 10% yearly discount rate would reduce Elevator 1's NPV value to $87 while Elevator 2's NPV would be $86. The $1 difference is a result of the discount rate's stronger effect on profits further in the future.

An important point to notice is the negative value for the forced spatial arbitrage (with a negative profit) at t_2 in Figure 4.8. In Figure 4.9, this negative profit is avoided by selecting to not ship any of the free capacity. Because the commodity firm has a contract, loss cannot be avoided with only one elevator.

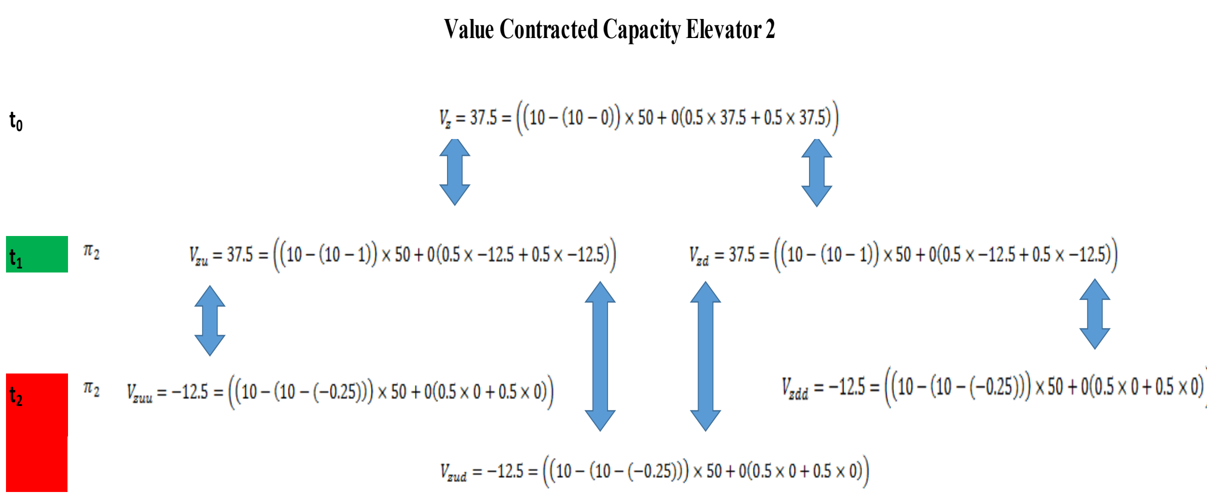

Figure 4.8. Application of Equation 15

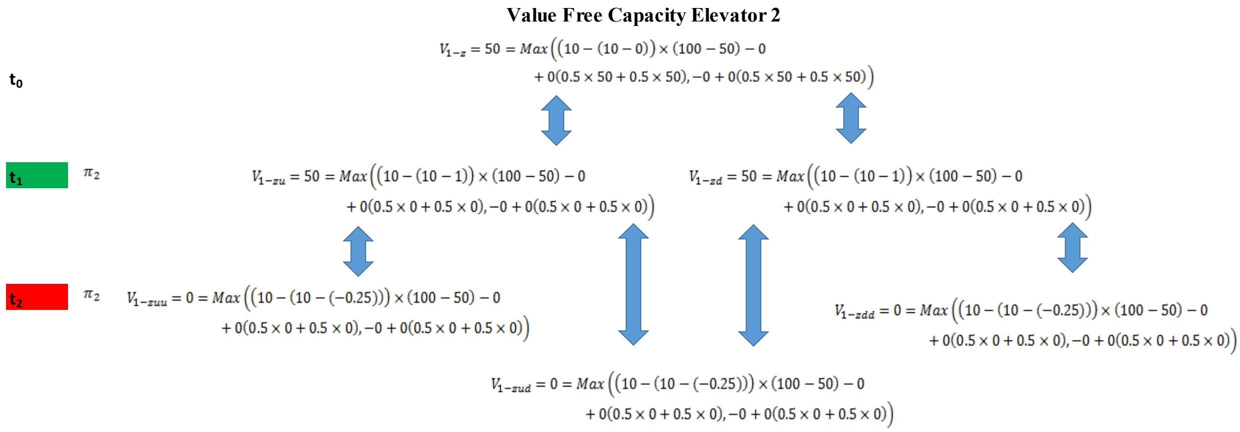

Figure 4.9. Application of Equation 16

Switching options gives a means to minimize the negative effect of contracting parts of the total capacity (currently incurred in Figure 4.8). To quantify this additional optionality, the value of a network utilizing this embedded flexibility must be valued. This valuation is done by applying Equations 18 and 19. Managers acting in their company's best interest want to maximize profits and minimize losses. Therefore, the logical behavior would be to use elevators with the most suitable market conditions to fulfill the contracted amount. Equation 18 is, therefore, applied to the elevators in a position to receive the largest arbitrage profits by shipping to the destination market, thereby fulfilling all contract obligations (Figure 4.10). Any capacity not used to fulfill contractual obligations, it is captured in Equation 19.

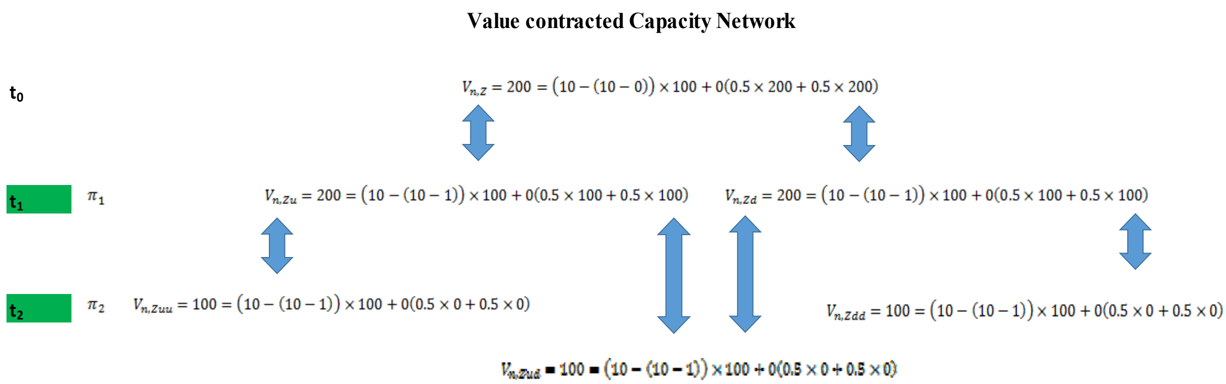

Figure 4.10. Application of Equation 18

Equation 18 gives the net present value for all future spatial-arbitrage profits (minus operating costs). The illustrative network has a value of $200. Equation 19 is not needed because all operating costs are set to zero and because only one elevator is profitable at a time. (There is no leftover capacity that could provide additional profit.) Management acting in the owner's best interest would be indifferent about which elevator would be used to fulfill contractual obligations at t_0 because neither elevator makes a profit nor a loss. At t_1, management would ship the full capacity from Elevator 1. This shipment would have fulfilled all obligations. Elevator 2 would not have shipped any part of its capacity. Management's decision would be the opposite at t_2.

Operating the network as one increases the profit from each elevator's arbitrage capacity by $12.50. The total increase in network value is $25, the same as an increased net present value of 14.3%. In other words, each elevator's management can increase the elevator's value by cooperating. When manipulating the contracted capacity (Z), an important concept is revealed. If 100% of the capacity is contracted, the network of cooperating and individual elevators is worth $150. With no contracting, the network is worth $200 either way it is managed. These equal values stem from one of the switching option's value drivers, flexibility. Without contracting, no flexibility is needed. Conversely, total contracting leaves no flexibility to utilize the embedded option. The example shows how jointly operating physical assets increases the profit received from spatial arbitrage under contracting (i.e., limited flexibility to act only when markets are favorable).

CHAPTER 5. RESULTS

To assess the optionality to participate in the grain trade between the United States, Brazil, or the Ukraine (origin locations) and Qingdao, China (destination market), the trading route must be divided into two steps. This division ensures a more realistic valuation. Companies with a demand for soybeans could buy from the local market or vertically integrate backwards to the export elevators at the origin markets. Vertical integration allows the firm to capture the profit reaped by the commodity traders currently supplying Qingdao. Physical assets to execute the trade are needed to capture the maximum profit. Remember the relationship between the reliance on physical assets and the profitability of commodity traders (higher reliance, higher profits) (Meersman, Reichtsteiner, & Sharp, 2012). The assets allow traders to control the trade flows. If the physical asset provides control for a logistical bottleneck, the trader might have access to severely depressed commodity prices in a geographical location. By controlling these bottlenecks, trading firms might be able to reap far higher margins (Wang & Li, 2010).

For a commodity firm to serve Qingdao, it must first gain sufficient control of a network connecting Qingdao to an origination market. This connection is provided by a logistical network (to the United States, Brazil, and the Ukraine). The network can, again, be divided into two steps; first, from Qingdao to the track price at the export elevators. To begin with, this chapter looks to the part of the value chain that connects the destination market to the export elevators. This case is used to explain the general behavior of switching options and how changes in their value drivers affect value (probability of profits, level contracted, and correlations). With the base case, a trader with a network reaching each of the four export elevator markets is valued with no contracting. Thereafter, contract levels, correlations and profit probabilities have been adjusted. Switching options change in value as a result of these sensitivities. The changes in value provide a general concept of switching options behavior across networks with different characteristics. The following section explores how embedded options affect the trader's decisions when selecting additional origins. Last, the optionality foregone by contracting is valued (the option to cease operation).

Destination Market to Export Elevator

To value the different optionalities associated with procuring grain from different export elevators, it is important to see the value of a network with full flexibility, defined here as a trader who does not contract any part of capacity. No contracting allows the trader to keep the optionality to not ship whenever the elevator faces unfavorable market conditions. The value of the export elevator network (with no contracting) is displayed in Figure 5.1. Each export elevator is assumed to have a capacity of 120 million bushels per year. The capacity of the total network per year is 480 million bushels. The monthly operating cost per export elevator is $1 million. The discount rate is assumed to be 6%. The different contracting levels are 0%, 25%, 50%, 75%, and 100% of total capacity.

Operated as standalone assets, each elevator has the following worth: Paranaguá: $0.90 billion (standard deviation: $0.57 billion), the Ukraine (Black Sea): $1.77 billion (standard deviation: $1.09 billion), PNW: $1.20 billion (standard deviation: $0.43 billion), and Gulf: $0.83 million (standard deviation: $0.44 billion). The export elevators valued as one network gives a total value of $4.70 billion (standard deviation: $2.10 billion); this value corresponds to each export elevator aggregated. Because there are no management imperfections (i.e., contracting), there is no value added by operating the elevators together (a result of no value from the optionality to switch).

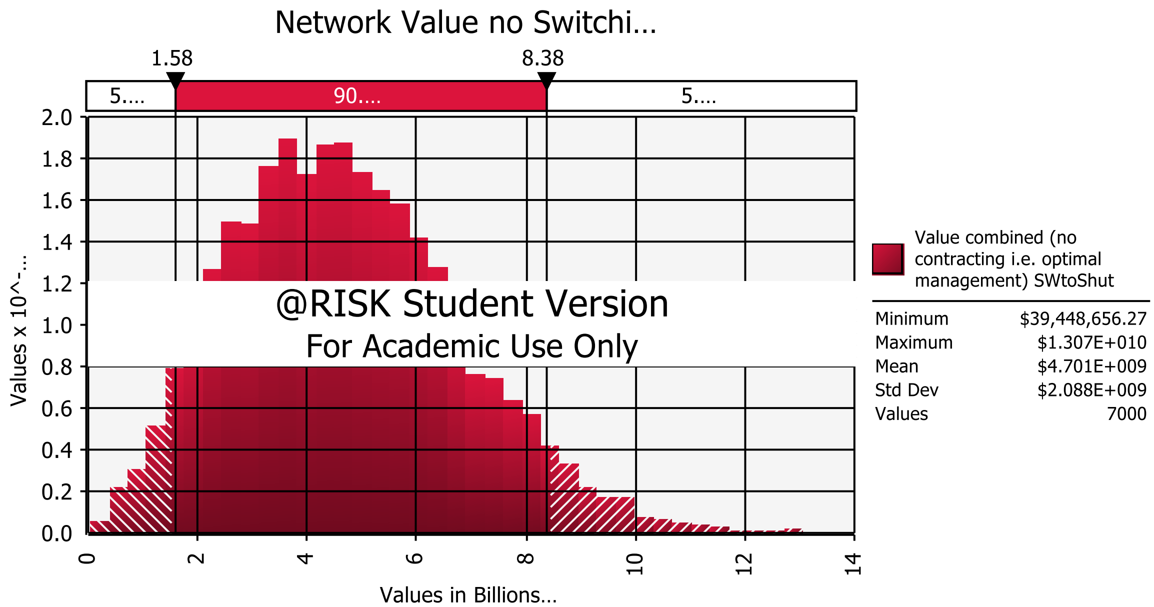

Figure 5.1. Network Value for Export Elevators

No Optionality to Switch the Origination Location

If the trading firm decides to contract (for reasons discussed in Chapter 4), the optionality to not ship any part of the capacity is effectively removed. If the commodity trader decides to contract 25% of production, the total net present value of the cash flow (the next 10 years) for this network decreases from $4.70 billion to $4.61 billon ((an $89 million decrease in value). This trader should only contract 25% if contracting implicitly provides $89 million or more in benefits.

The value provided by the flexibility to alternate the origin location can only be assessed for the network, not for individual origins (due to the fact that one location cannot switch). Additional flexibility can, however, be valued for one elevator if the elevator comes in addition to another location. To illustrate the effect of the optionality to switch, one first needs to understand the changes that contracting imposes on a network that does not take advantage of the embedded switching flexibility.

Table 5.1 displays the minimum, maximum, mean, and standard deviation for the network value according to the percentage of total capacity which is committed to being shipped for each time period. The network's maximum value changes minimally over the five contracting conditions because each export elevator has a relatively high likelihood of profiting from shipping and because everything could go in the traders' favor for a very small portion of the simulations. This profit distribution results in a marginal effect in relation to the best-case scenario relative to the base case. The minimum value, on the other hand, experiences a rapid change for the different cases. Each quarter of free capacity that is contracted results in an average adverse move in the minimum value by $1.5 billion. Going from no contracting to complete contracting magnifies the worst-possible outcome of the simulation from -$79 million to -$6.21 billion for a network with no switching. Additional contracted capacity decreases the network's mean value by an average of $89 million per additional quarter of capacity contracted. The standard deviation, relative to the mean, goes through the opposite change; each increase in contracted capacity leads to an average increase of $96 million. The increases for the standard deviation are caused by the lack of flexibility which, again, makes the trader more vulnerable to the market's adverse price moves (because they cannot be avoided by ceasing all shipping). These results are displayed in Table 5.1 and are shown graphically in Figure 5.2.

Table 5.1. Export Elevator Network Value with no Switching (in Millions)

Bushels Contracted	0 million	10 million	20 million	30 million	40 million
Percentage of Total Capacity Contracted	0%	25%	50%	75%	100%
Minimum Value	-$79	-$1184	-$2691	-$4847	-$6214
Maximum Value	$14850	$13200	$13210	$13380	$14260
Mean Value	$4700	$4611	$4522	$4433	$4344
Standard Deviation	$2087	$2178	$2280	$2383	$2470

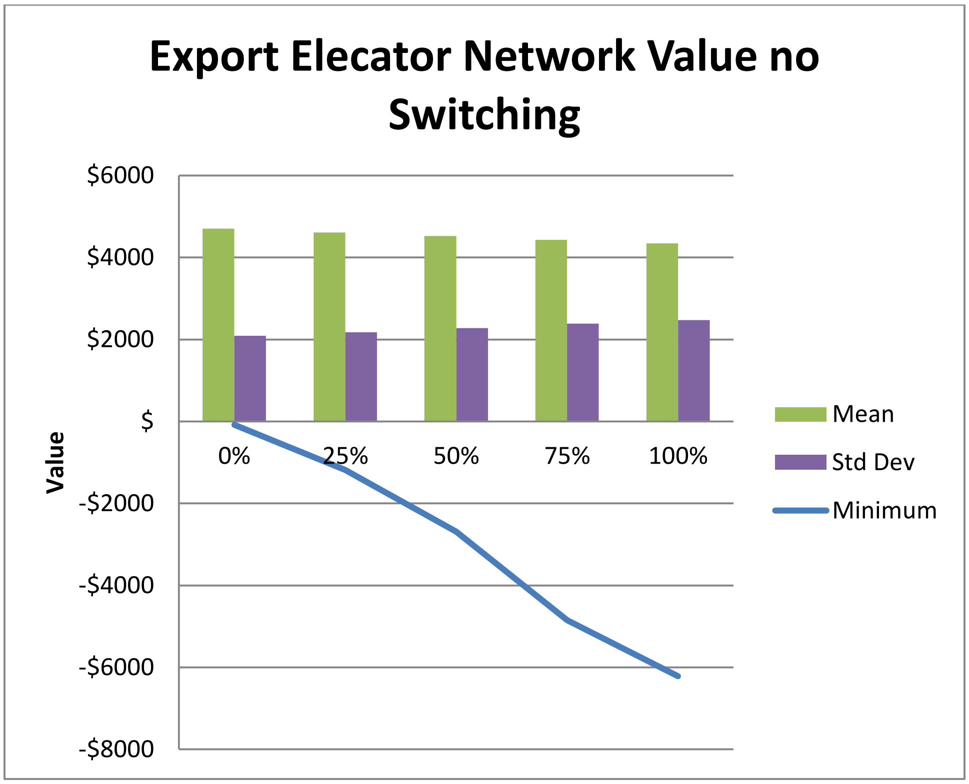

Figure 5.2. Changes in the Export Elevator Network's Value by Contracted Capacity and no Optimality to Switch

Optionality to Change the Origin Location

The base case shows an increased potential for loss, a decreased mean value, and an increased standard deviation as a result of contracting when no origination flexibility is present. To circumvent these adverse effects while maintaining the optionality to contract parts of capacity, commodity traders need to increase their flexibility at origin locations. If the trader operates the network as one (either through ownership or partnerships), these adverse value changes can be lessened. The trader can decrease losses for contract obligations in unfavorable markets, assuming that commodity traders change their origin locations according to the most favorable market conditions for the contracted capacity and ship the leftover capacity whenever feasible. This flexibility effectively removes some disadvantages of locking up capacity. The network's value with the switching option changes across the five contracting levels in accordance with Table 5.2.

Table 5.2. Export Elevator Network's Value with Switching (in Millions)

Bushels Contracted	0 million	10 million	20 million	30 million	40 million
Percentage of Total Capacity Contracted	0%	25%	50%	75%	100%
Minimum Value	-$79	-$612	-$1477	-$3055	-$6214
Maximum Value	$14850	$13200	$13210	$13380	$14260
Mean Value	$4700	$4693	$4661	$4589	$4344
Standard Deviation	$2087	$2099	$2148	$2235	$2470

The first important point is that the values for complete contracting and no contracting are the same for a network that engages in switching behavior and for one that does not. Intuitively, the reason is the fact that 100% contracting removes all flexibility, even in a network that can switch. No contracting results in complete flexibility, and the optionality to switch has no value because it does not increase flexibility. The maximum value is also the same. One can see important differences in the values for the partially contracted scenarios. Table 5.3 shows favorable increases in the minimum and the mean value, along with the reduced standard deviation. The increased the mean value is the value of the switching option.

Table 5.3. Export Elevator Network's Benefits from the Optionality to Switch (in Millions)

Bushels Contracted	0 million	10 million	20 million	30 million	40 million
Percentage of Total Capacity Contracted	0%	25%	50%	75%	100%
Increase in Minimum Value	$0	$572	$1214	$1792	$0
Increase in Mean Value	$0	$82	$139	$156	$0
Decrease in Standard Deviation	$0	-$79	-$132	-$148	$0

The switching option is worth $156 million when 75% of the capacity is contracted, $139 million when 50% is contracted, and $82 million when 25% is contracted. In terms of the mean value's percentage increase, it is 4%, 3%, and 2%, respectively for the 75%, 50%, and 25% contracting-level scenarios. The behavior of the switching option across the contracting levels illustrates an important point. When 75% of the total capacity is contracted, the increase for the mean value is at its largest. Logically, if switching options gain their value from providing needed flexibility, the mean value of the switching option will surge as contracted capacity increases until an amount of capacity is contracted so that the switching option no longer has sufficient free capacity to switch; this point is referred to as the excessive contracting threshold. By contracting 75%, the network does not reach this threshold because the profit distributions for the export elevators have relatively low probabilities of negative returns. The excessive contracting threshold occurs somewhere between the 75% and 100% contracting levels. Based on the Akaike Information Criterion, the distributions that best represent the historical profit for each export elevator only have a 0.08 probability of negative profits for Paranaguá, 0.15 for the Black Sea, 0.06 for PNW, and 0.22 for the USG.

With a low probability of negative profit, the free capacity needed for the switching option to start decreasing in value is rather high. The switching option not only decreases in absolute value, but also in terms of the percentage of value added to the network by the option. This concept is explained further by examining the network of export elevators in a scenario where the probability of negative profits is manipulated to be higher.

Figure 5.3 illustrates where the excessive contracting threshold would occur. The graph also shows how contracting hurts the mean value for a network that is operated as standalone assets far more than a network managed together (until 100% is contracted). The network value foregone by contracting in the scenarios is also illustrated. Equation 24, which refers to the existence of an optimal level where traders can contract the given amount without incurring a reduction in the mean value, exists somewhere between the 0% and 25% contracting levels. At the 50% contracting level, Equation 24 is violated, however, the reduction for the mean value is less than 1%.

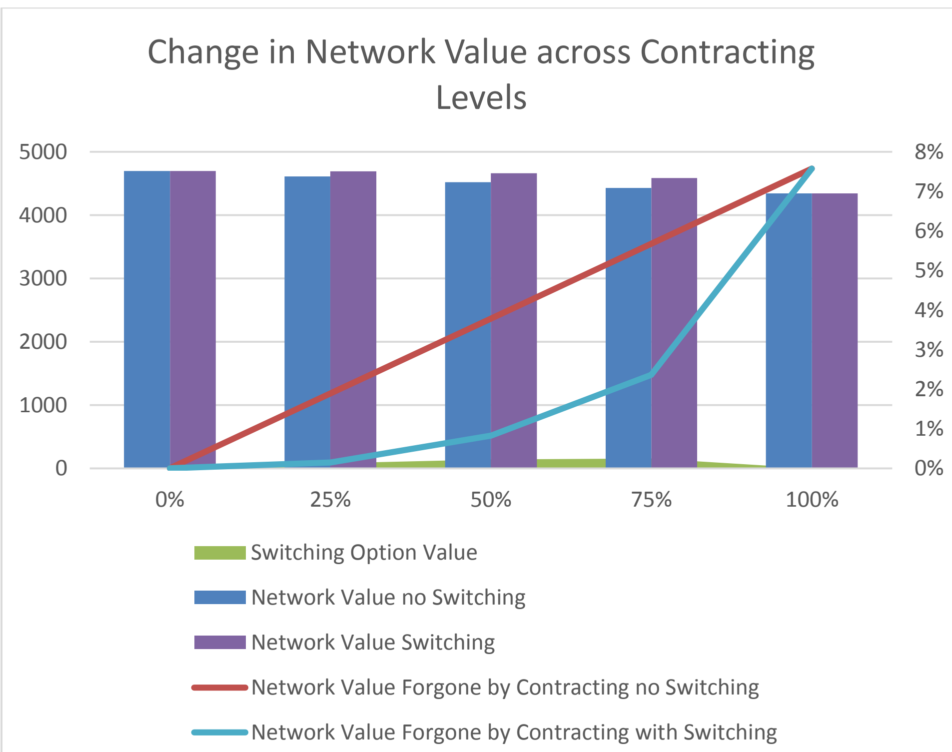

Figure 5.3. Changes in Network Value across the Contracting Levels for the Export Network

Option Value with Reduced Probabilities for Profit

If the probabilities of negative results for each elevator increased, the switching option would have an increased value relative to the mean total value for the network when contracting approaches the excessive contracting threshold and then decrease when contracting exceeds this point. Switching options gain value from the flexibility they create to divert the contracted capacity to the most favorable market; intuitively, the relative value will then be low when this optionality is not needed (due to low or no probability of negative returns from shipping). It is the relationship between the profits' probability distribution, or more specifically the probability of negative returns, and the correlation between the locations that determines the value of the switching option.

Figures 5.4.-5.7 display the best-fitting distributions based on the Akaike Information Criterion of historically profitable data for export elevators in red. These data provide distributions with probabilities of negative results: 0.08 for Paranaguá, 0.16 for the Black Sea, 0.07 for PNW, and 0.22 for USG. When reducing the profit (and increasing the loss) by deducting $1 per bushel, the corresponding probabilities of negative profits increase to 0.50 for Paranaguá, 0.30 for the Black Sea, 0.38 for PNW, and 0.55 for USG (displayed by the distributions in blue for Figures 5.4-5.7. The price distributions for the PNW and the USG have striking shape similarities, however, the profit probabilities vary vastly. Paranaguá and the Black Sea locations stand have greatly differing distributions.

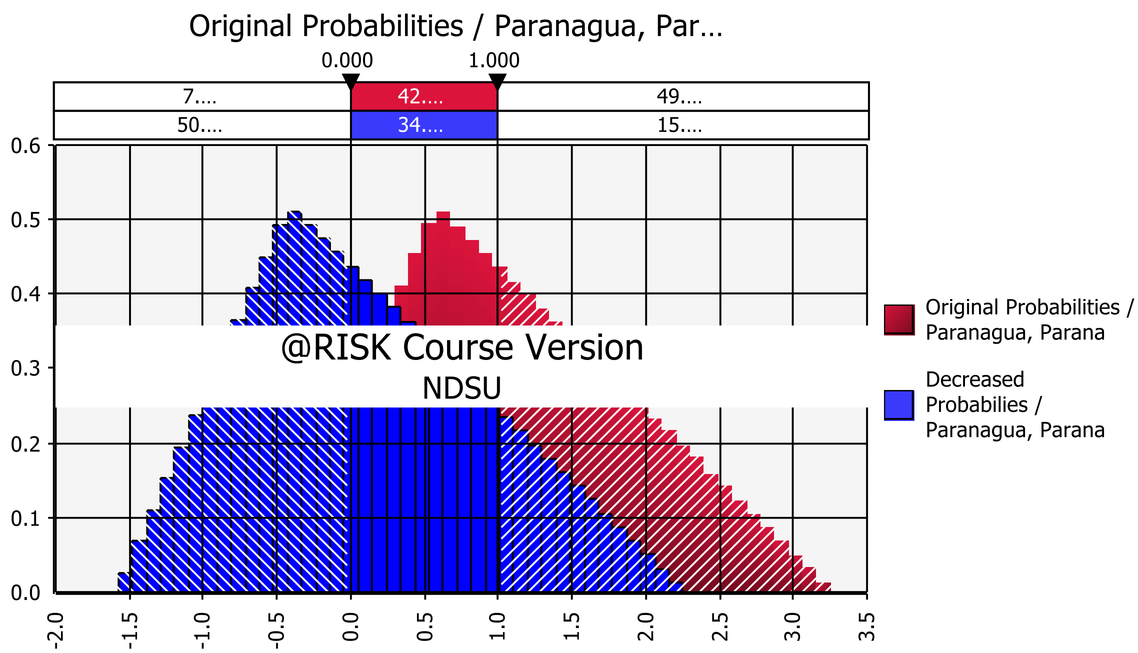

Figure 5.4. Original and Manipulated Profit Probabilities for Paranaguá

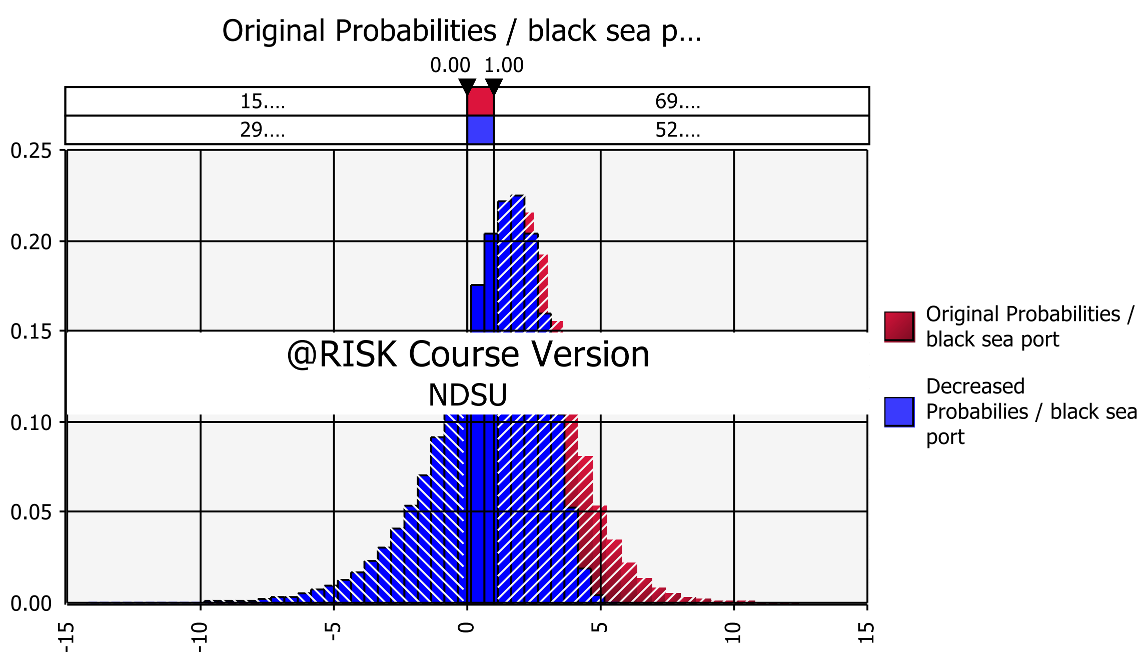

Figure 5.5. Original and Manipulated Profit Probabilities for the Black Sea

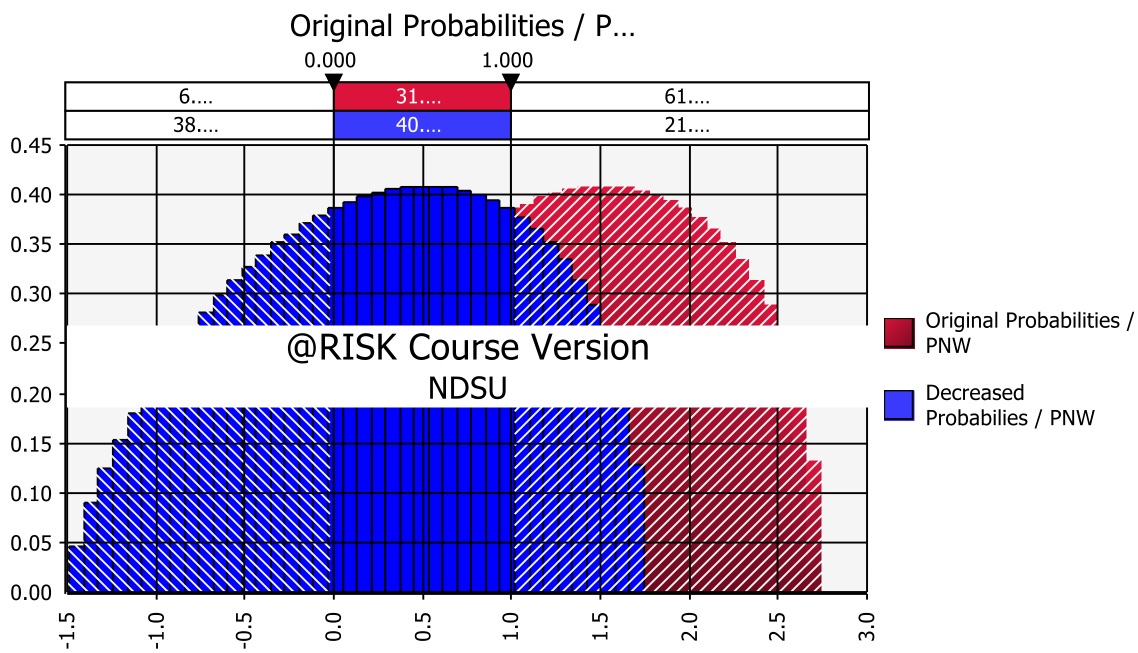

Figure 5.6. Original and Manipulated Profit Probabilities for PNW

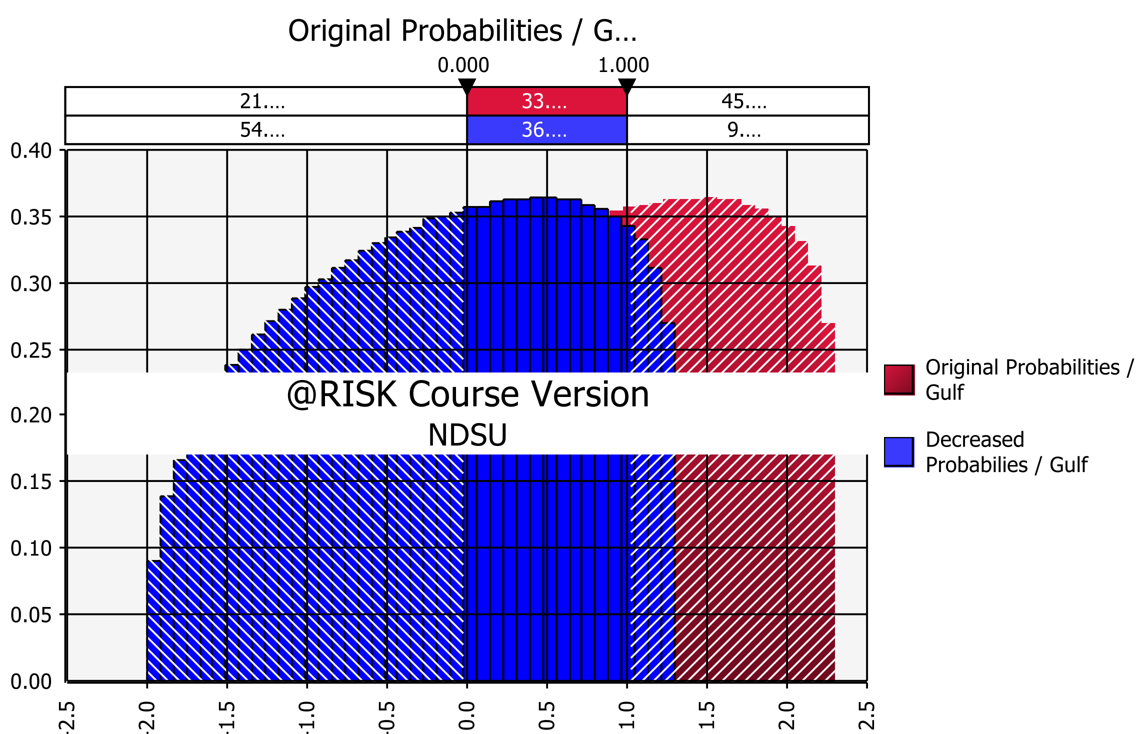

Figure 5.7. Original and Manipulated Profit Probabilities for the USG

These changes in the profit distributions provide large alterations for valuing the switching option. First, the behavior of the switching option across the different contracting levels proves the concept of an excessive contracting threshold. From Figure 5.8, one can see the values for the switching option: (1) the minimum value stays at zero across all levels; (2) the maximum value and the standard deviation increase with the amount contracted; and (3) the value of the switching options increases from the 25% contracted condition to the 50% condition and then decreases when 75% is contracted. These changes in the value prove that the excessive contracting threshold for this network of export elevators (with manipulated profit functions) lies somewhere around the 50% contracting level (above 25% and below 75%).

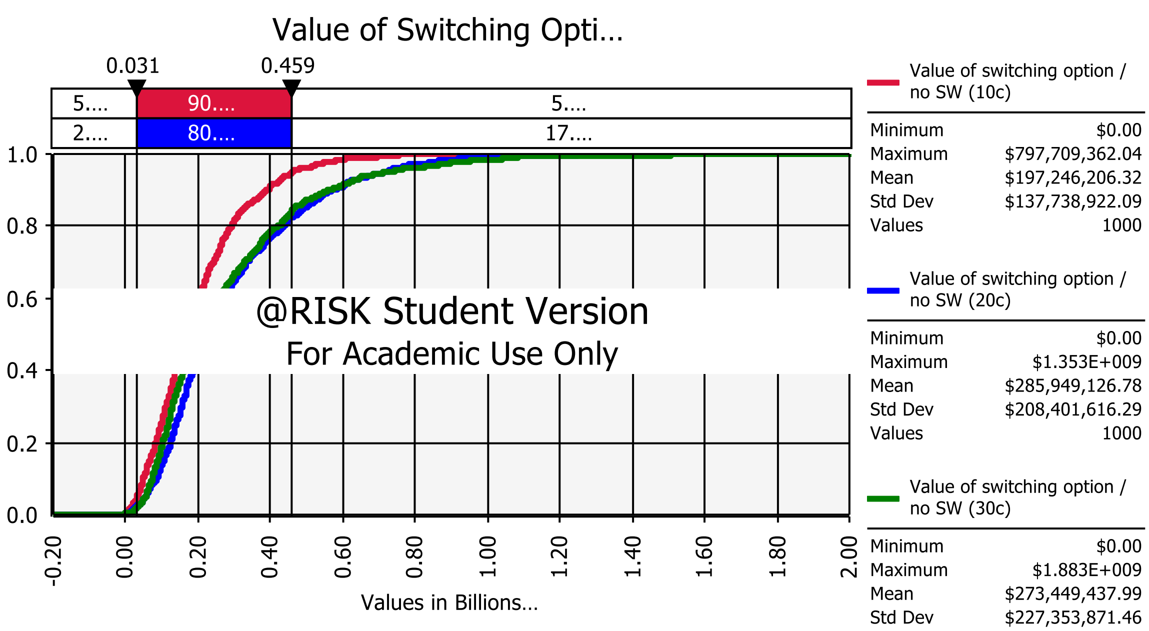

Figure 5.8. Switching-Option Value with a Decreased Probability for Profit across Contracting Levels

For the base case, the increased value provided by the optionality to switch was 4%, 3%, and 2%, respectively, for the 75%, 50%, and 25% contracting levels. With the decreased profit probabilities, the percentage increases in value across the respective contracting levels were 32%, 25%, and 14%. The increased portion that the switching option's total value comprises illustrates two important concepts. First, even though the switching option's value decreases after the excessive contracting threshold is reached, the percentage of the total network value it creates does not. Second, the switching option is far more valuable in a network with large price instability across geographical origins and a high likelihood of negative profits for the individual locations. A network that contracts 50% of its capacity and utilizes the optionality to switch has a 0.18 probability of being worth less than zero over the next 10 years. If the network does not take advantage of this embedded optionality, the probability of a value less than zero increases to 0.25. (The probability density function is displayed in Figure 5.9)

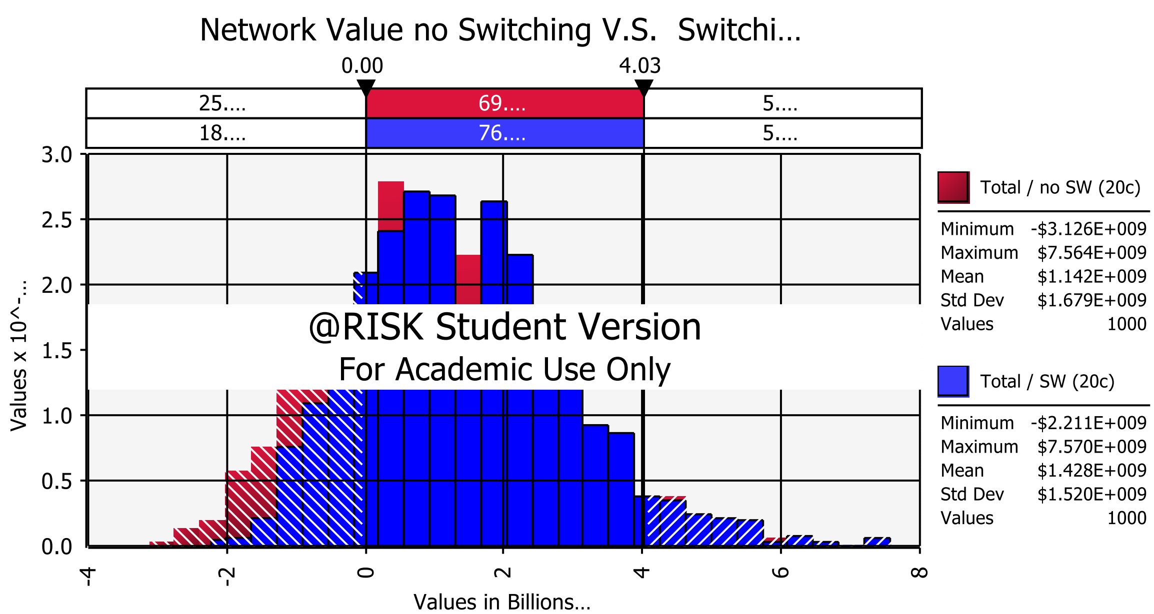

Figure 5.9. Probability Density Function for an Export Elevator Network with the Optionality to Switch vs. Network that does not Use this Optionality

After going through the results for a decreased probability of profits on the switching options' value, another important question is the effect of higher correlations between the network's geographical locations. Correlations and profit probabilities are the determinants of the switching option values.

Option Value with a Higher Correlation between Origin Locations

In the case with decreased profit probabilities, the percentage increase in value across the respective contracting levels was 14%, 25%, and 32% when accounting for the optionality to switch. The switching option gains value by diverting contracted capacity to the most favorable markets. This diversion can only be accomplished if there is a more favorable market for the contracted capacity. An important aspect is the effect of increased correlations on the option value. The original correlations can be seen in Table 5.4. New simulations were run with a 10% and 50% increase in correlations, and one scenario with perfect correlations was run. Table 5.5 displays the 50% increased correlations; several elevators are perfectly correlated as a result. Table 5.6 displays the correlations between prices that are not adjusted for transportation costs.

Table 5.4. Original Correlation between Export-Elevator Profits

	Paranaguá	Black Sea	PNW	USG
Paranaguá	1.00			
Black Sea	0.38	1.00		
PNW	0.79	0.39	1.00	
USG	0.83	0.51	0.96	1.00

Table 5.5. 50% Increased Correlation between Export-Elevator Prices

	Paranaguá	Black Sea	PNW	USG
Paranaguá	1			
Black Sea	0.57	1		
PNW	1	0.59	1	
USG	1	0.77	1	1

Table 5.6. Correlations between Export-Elevator Prices

	Paranaguá	Black Sea	PNW	Gulf
Paranaguá	1			
Black Sea	0.55	1		
PNW	0.94	0.50	1	
USG	0.95	0.54	0.99	1

With 10% increased correlations, the total network value under the 50% contracting condition reduces the total value of a network with the optionality to switch by $8 million (0.6%). This decrease in total value is completely reflected in the reduced switching option (which decreases by 2.7%). (See Figure 5.10 relative to Figure 5.8.)

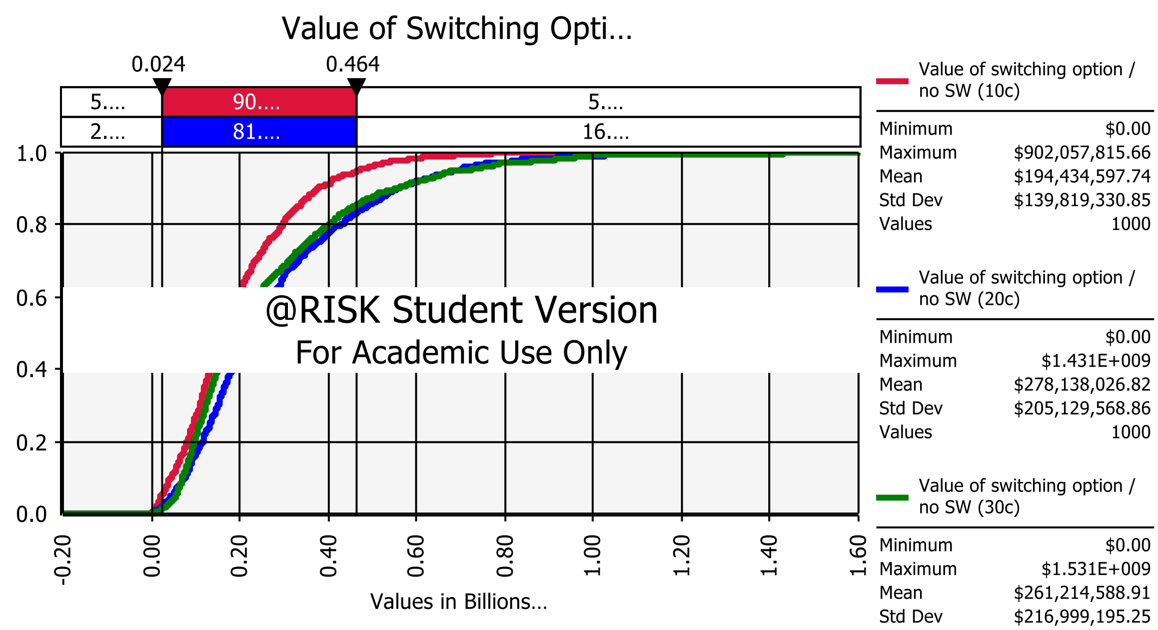

Figure 5.10. Value of Switching Option with 10% Increase in Correlations

If correlations are increased by 50% relative to the original case, the reduction in total network value reaches $25 million, which is 1.7% in percentage terms (8.7% for the switching option). Interestingly, the effects of increased correlations are magnified as contracted capacity increases. For the commodity trader who contracts 75% of the total capacity, the 50% increased correlation results in a 10.7% reduction in the switching option value (compared to 8.7%). This magnified reduction is likely a result of the need to shift a larger volume of the capacity towards cheaper markets and the lower likelihood of large arbitrage profits between the markets due to the increased correlation. (See Figure 5.11 relative to Figure 5.8 and 5.10.)

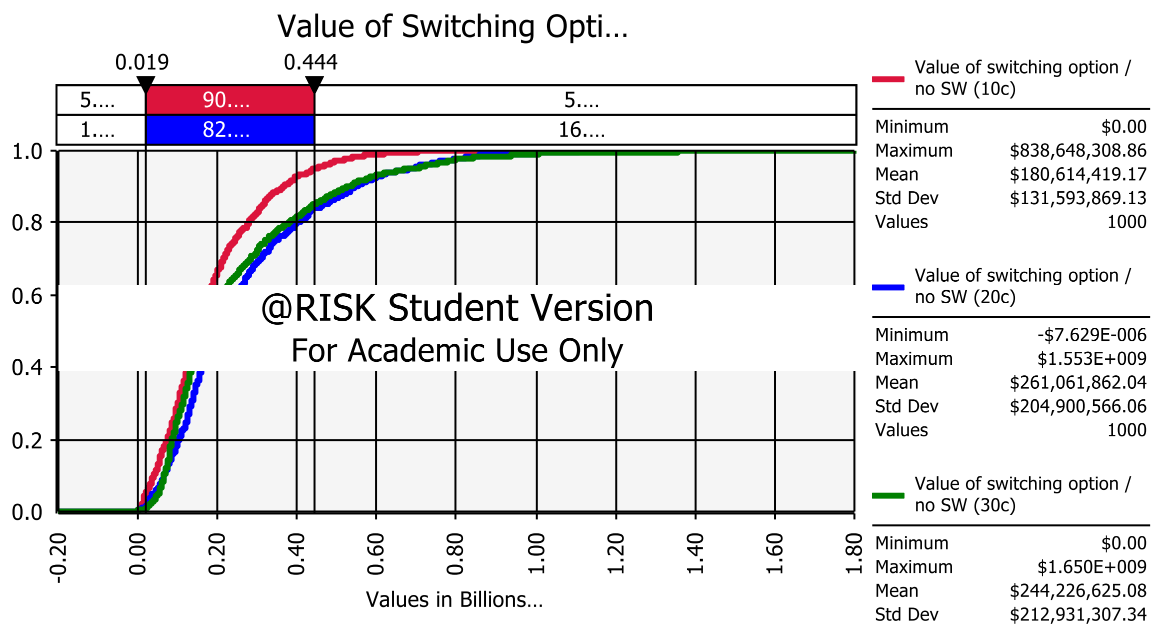

Figure 5.11. Value of Switching Option with 50% Increase in Correlations

If correlations become perfect, the switching option still has value. Even when the prices move in perfect correlation across locations, the profit still differs across the locations (in accordance with the distributions). This geographic difference still provides value because contract obligations can be honored with the most beneficial market price, proving that switching option has value even when correlations are high. An interesting observation in the case of perfect correlations is the shift in the excessive contracting threshold. With all other correlations, this threshold occurred somewhere between the 25% and 75% contracting levels; with perfect correlations, this threshold is moved to somewhere after the 75% contracted level (Figure 5.12).

Table 5.7 shows where the switching option starts to decrease in value relative to the contracting level and increased correlations.

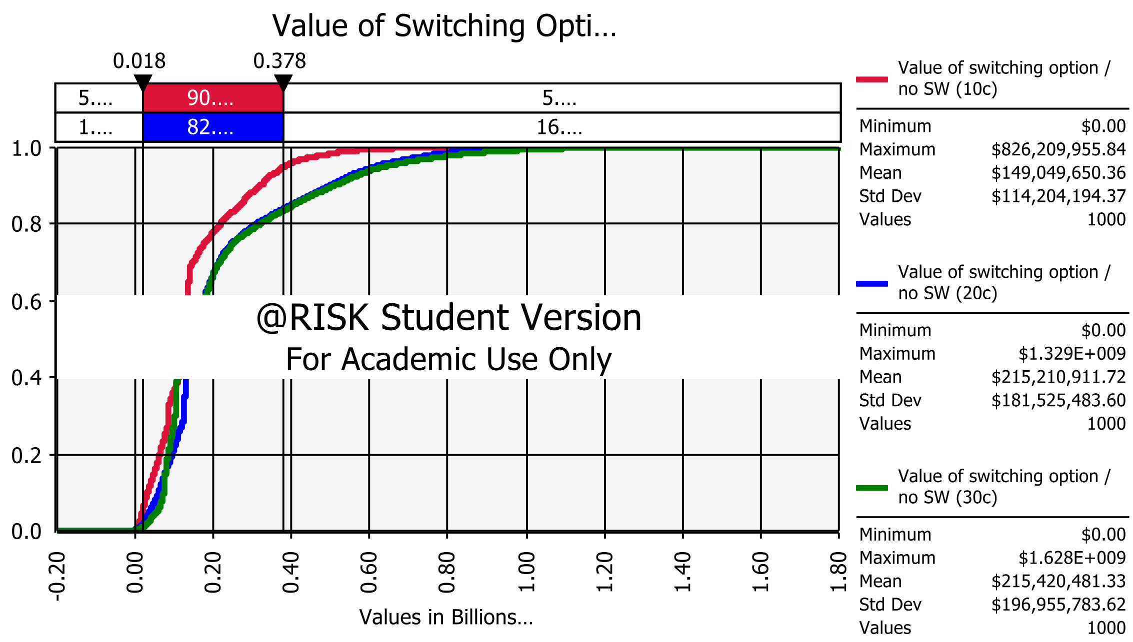

Figure 5.12. Value of Switching Option with Perfect Correlations

Table 5.7. Excessive Contracting Threshold (in Millions)

Contracting level	25%	50%	75%
Original Correlation	197	286	273
10% Increased Correlation	194	278	261
50% Increased Correlation	180	261	244
Perfect Correlation	149	215	215

Note: Pink highlight signifies where the excessive contracting threshold occurs.

Changes in the total value for a network that has the optionality to switch are far higher when correlations increase relative to a network which does not switch origins. Following an increase to perfect correlations, a network utilizing the switching option will decrease in value by $71 million ($1.428 billion-$1.357 billion) while a network without the optionality to switch changes less than $1 million in value. Not utilizing the embedded switching option increases the 5% value at risk from -$1.26 billion to -$1.87 (Figure 5.13).

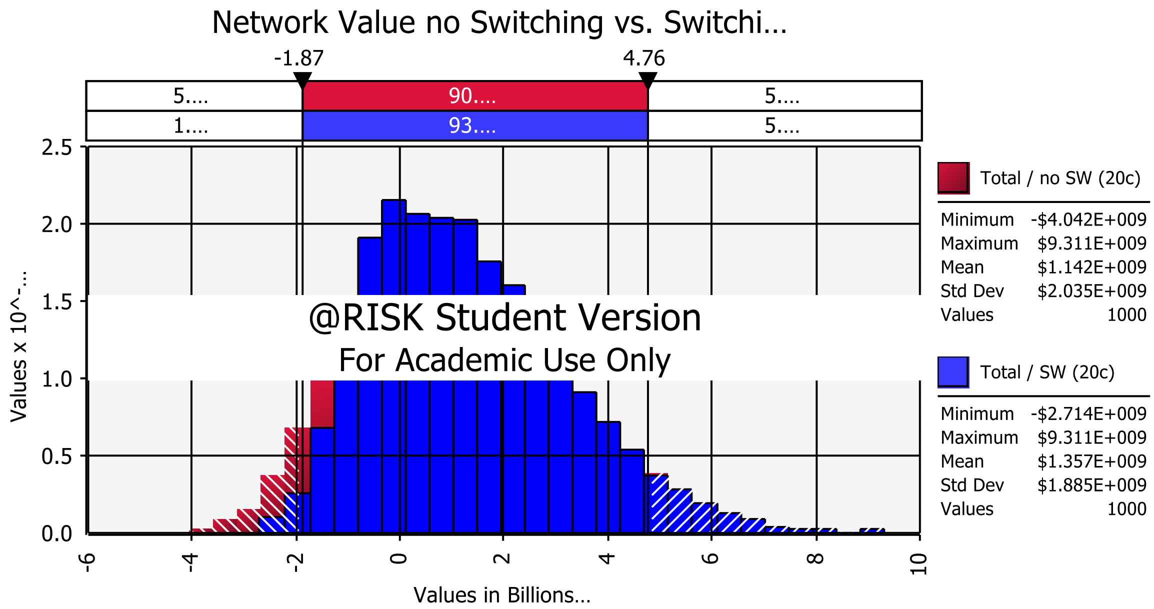

Figure 5.13. Network Value for no Switching vs. Switching

Figure 5.14 provides a visual summary of the sensitivities conducted as well as their effect on the switching-option value. The line with the lowest value represents the base case. The line with the highest option value represents the sensitivity with the increased probability of negative profits. The increased option value proves that origination flexibility has more worth and that geographically diversified trading firms have a larger advantage in markets with a higher probability of negative profits. Additionally, Figure 5.14 displays how the switching option gradually decreases in value as correlations increase. This decrease provides the conclusion that option values are greater when there is a lower correlation between spatial-arbitrage profits. As the correlation increases, the origination flexibility becomes less valuable. For commodity traders, this reduction in value has important implications: (1) large trading firms will have an advantage with inefficient markets where correlations are low, and (2) as markets become more integrated and efficient, the large trading networks' advantage over smaller traders decreases (as the embedded switching option in large networks loses value). These implications shows how large trading firms benefit from market inefficiencies.

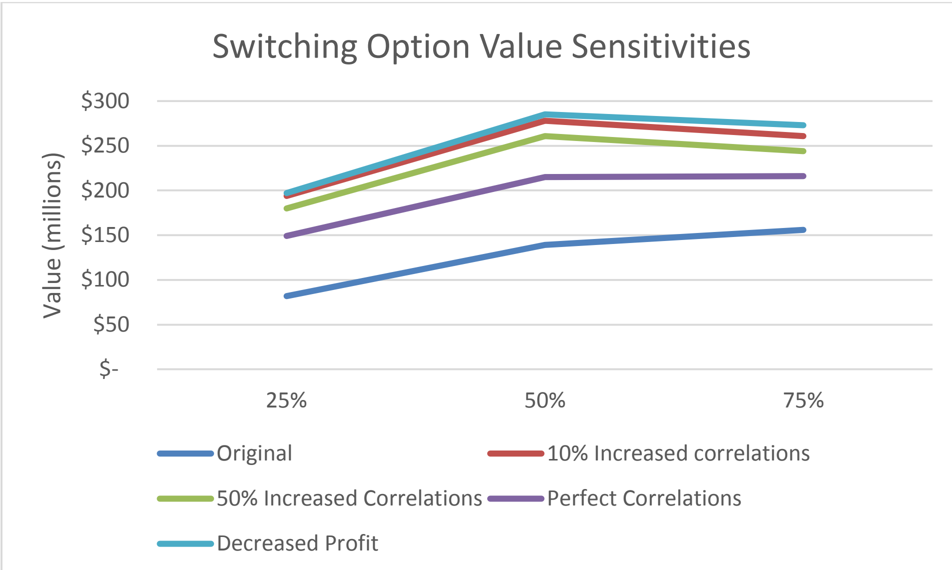

Figure 5.14. Changes in the Switching Option Values across Various Markets

Export Elevator to Country Elevator

The next section focuses on networks created by further backwards integration from each of the export elevators to their corresponding country elevators. The values provided are for the total network of elevators that can supply the export locations. In other words, the arbitrage opportunity (or profit opportunity) can be captured by shipping local grain (at the country elevator) to the export elevator. It is important to realize that arbitrage opportunities are the price differences between the current price at the country elevator and the track price at the respective export elevator. The profit from those price differences belongs to the commodity trader controlling the export elevator (and its corresponding shipping route). When a trader controls this port of entry to a geographic area, the next step in the vertical integration would be to acquire a country elevator, thereafter horizontally integrating at the country-elevator level to secure access to several local markets. This final step to capture the value chain would secure complete control of the grain flow from that location to the final destination market in Qingdao.

Paranaguá to Country Elevators in Brazil

Country elevators in Brazil are assumed to have a fixed cost of $215,000/month and a capacity of 2 million bushels per month (24 million/year). The transportation is done by truck and is estimated based on the cost of hauling per mile. All elevators and their distances to Paranaguá (the export elevator) are listed in Table 5.8.

Table 5.8. Distance to Destination Market

Origin	Distance to Paranaguá, Parana, in Miles
Barreiras, Bahia	1258
Rio Verde, Goias	849
Rondonopolis, Mato Grosso	998
Sorriso, Mato Grosso	1338
Triangulo Mineiro, Minas Gerais	728
Ponta Grossa, Parana	136
Ijui, Rio Grande do Sul	496
Passo Fundo, Rio Grande do Sul	394
Sorocabana, Sao Paulo	256

Each country elevator has a positive net present value when no part of the capacity is contracted except the Barreiras, Bahia location. Fitting the historical data to a distribution shows that, historically, this location only makes a profit 7.4% of the time by shipping to Paranaguá (Figure 5.15). Most likely, this low probability of profit is due to the relative distance to the destination market (1,258 miles). The elevator does, therefore, negatively impact the network's value for the commodity trader (in this case) and is, therefore, excluded from further analysis.

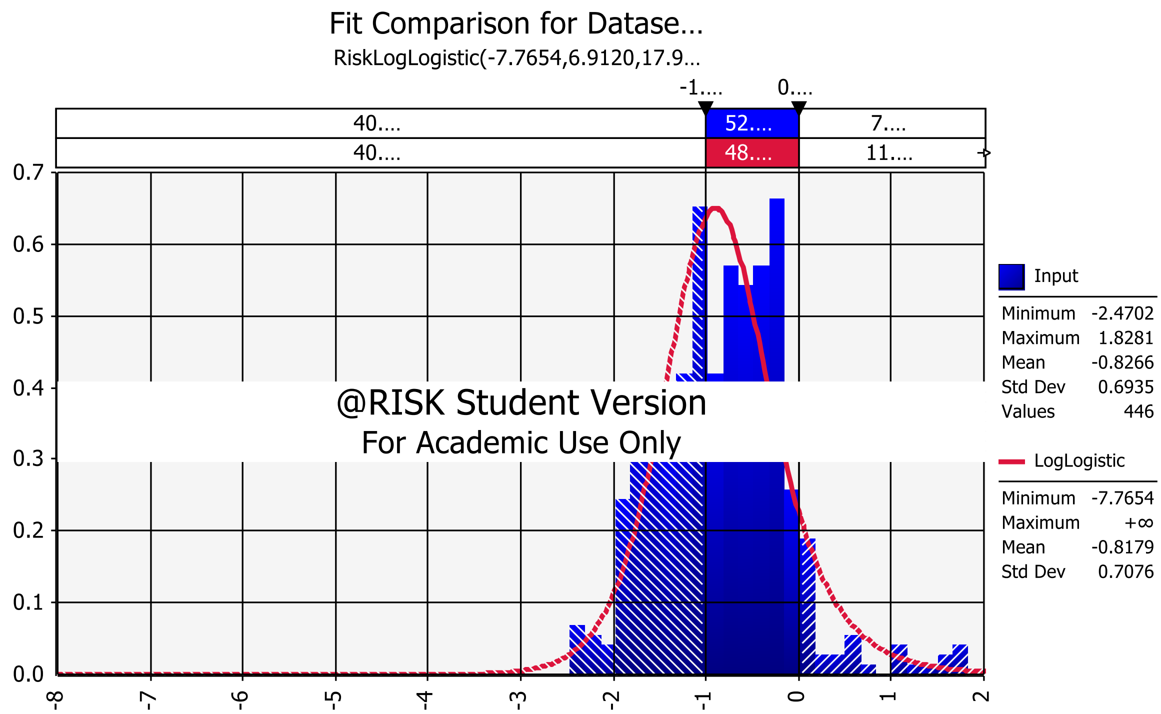

Figure 5.15. Barreiras, Bahia, Profit Distribution

The real-option model essentially provides the answer for two things: first, the net present value of all cash flows associated with an elevator as a standalone asset and, second, as part of a network. The model does not tell the market value of an elevator in general; only the value of all future cash flows provided by the asset given the flexibility level available and a 6% discount rate. An elevator might have a market value of $10 million, however, the value of the future cash flows for a specific trading firm might be $5 million or $15 million, depending on how the elevator fits with the trader's current network of physical assets. This value provides important guidance. Based on the commodity trader's destination markets and contracting levels, one can provide the trader with a current value. Table 5.9 displays the values for each elevator as a standalone asset across contracting levels that range from no contracting to 100% contracting. The total of these values is the same as the value of a country-elevator network that does not utilize the optionality to switch the origin location. The value of a network not utilizing its optionality to switch is the same as the value of a network that switches when the option value is deducted. The values for all elevators as standalone assets and as part of a network are displayed in Table 5.9.

Table 5.9. Network and Country-Elevator Values across Contracting Levels (in Millions)

Bushels Contracted (Millions)	0	2	4	6	8	10	12	14	16
Percentage of Total Capacity Contracted	0%	13%	25%	38%	50%	63%	75%	88%	100%
Rio Verde, Goias	$26	$22	$19	$16	$13	$10	$7	$4	$1
Rondonopolis, Mato Grosso	$2	-$4	-$10	-$16	-$22	-$29	-$35	-$41	-$47
Sorriso, Mato Grosso	$8	$2	-$4	-$9	-$15	-$21	-$26	-$32	-$38
Triangulo Mineiro, Minas Gerais	$17	$11	$6	$1	-$5	-$10	-$15	-$21	-$26
Ponta Grossa, Parana	$120	$119	$119	$119	$119	$118	$118	$118	$117
Ijui, Rio Grande do Sul	$59	$57	$56	$55	$54	$52	$51	$50	$49
Passo Fundo, Rio Grande do Sul	$86	$85	$84	$83	$83	$82	$81	$81	$80
Sorocabana, Sao Paulo	$63	$62	$60	$59	$57	$56	$54	$53	$51
Network Value no Switching	$379	$355	$331	$307	$283	$259	$235	$211	$187
Network Value Forgone by Contracting no Switching	0%	6%	13%	19%	25%	32%	38%	44%	51%
Switching Option Value	$0	$24	$46	$66	$81	$87	$77	$49	$0
Network Value with Switching	$379	$379	$377	$373	$364	$346	$312	$260	$187
Network Value Forgone by Contracting with Switching	0%	0%	1%	2%	4%	9%	18%	31%	51%

Table 5.9 reveals several important aspects of switching options and the individual locations in Brazil. Distance to the export elevator is an important determinant of profitability. For a trader with an export elevator in Paranaguá, a country elevator in Ponta Grossa (136 miles away) has value of $120 million while an elevator in Sorriso (1,338 miles away) only has a value of $8 million when no capacity is contracted. The impact of this decreased profitability is magnified when parts of the capacity are contracted. The respective values change to $117 million and -$38 million when all capacity is contracted. The differences in the probabilities for profit give value to the switching option.

One can clearly see that a commodity firm should value elevators with the same operating costs and different locations differently. If the trader seeks to fulfill a fixed demand at the export elevator (i.e. contracting), the elevators have a far higher value when managed as a network than as standalone assets. For example, with 50% contracted and managed as single assets, the network has a value of $283 million; managed together, the value increases to $364 million (a 29% increase). This large value increase can be partially explained by the low correlation between profit opportunities, as displayed in Table A4. The value created by managing the country elevators as a network across different contracting levels is shown in Figure 5.16. All values are given for both a network of independently operated assets and a network of elevators with the optionality to switch that are managed together.

Figure 5.16 shows two important properties of the switching option. First, the excessive contracting point, which occurs where the value of the switching option peaks (around the 63% contracting level). Second, the behavior of the graph depicting network value foregone by contracting with and without the optionality to switch. One can see in the graph, and in Table 5.9, that up to 13% of the capacity can be contracted without incurring any value reduction. This level is defined as the optimal contracting threshold (the maximum amount contracted without violating Equation 24). Commodity traders who do not contract this amount forego a “free lunch.” For the Brazilian network, a trader can contract up to 25% of the capacity and only forego 1% of the total network value.

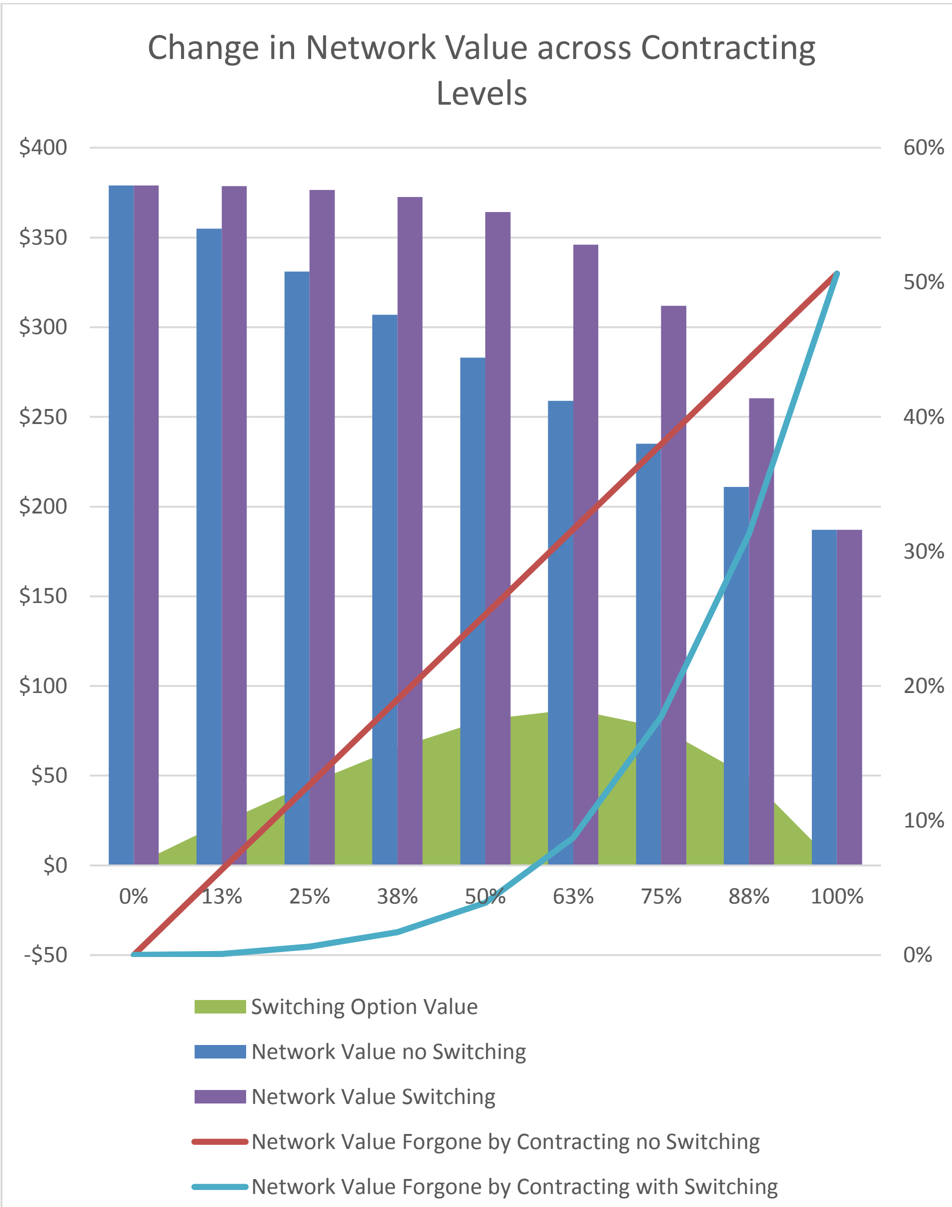

Figure 5.16. Network Behavior across Contracting Levels for Brazil

The U.S. Gulf to Country Elevators

The network supplying the Gulf export elevator has a net present value of $205 million or an average of $8.9 million per elevator. The Gulf network experiences large synergy effects from operating as a network. Figure 5.17 displays the network values and the amount of total value that is foregone by contracting. Managed as a network, a trader can contract 5% of the capacity and forego 0% of network value compared to a 10% decrease in the net present value if the elevators are managed as standalone assets. When contracting reaching 10%, the network value is reduced by 1% with the switching option and 21% without that option. If a trader contracts 52% of the capacity, the network with a switching option has a net present value of $172 million versus -$27 million without the flexibility to switch origins. The elevators in the network are listed in Table A2.

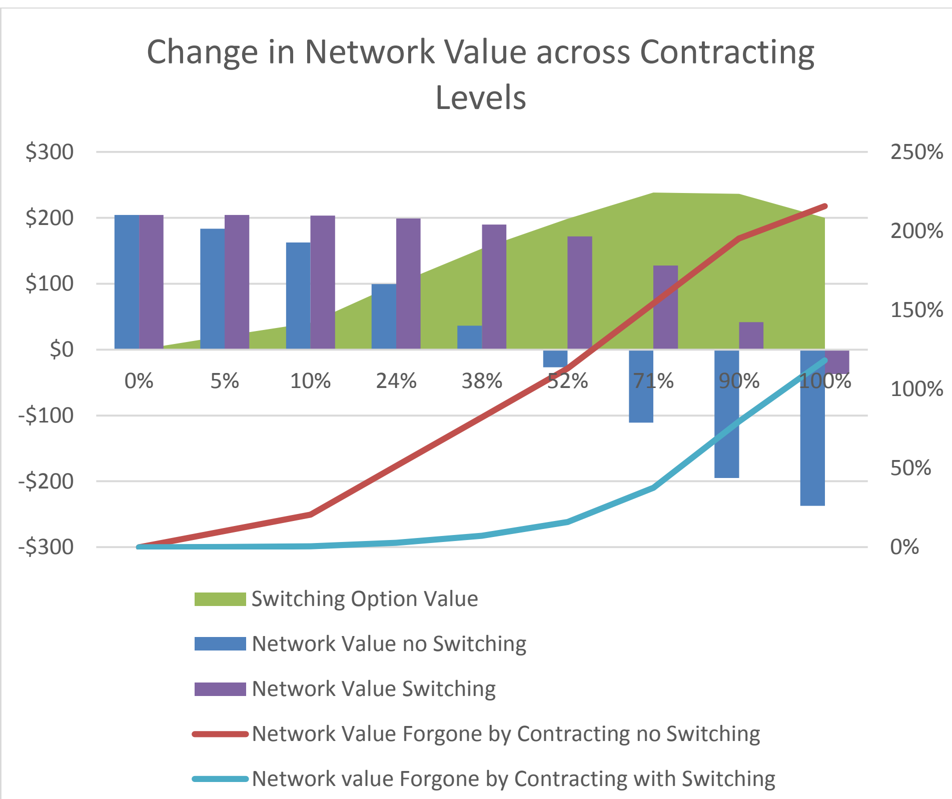

Figure 5.17. Network Behavior across Contracting Levels the USG

Network Expansion

Commodity traders gain advantages (or synergy effects) from managing large networks. Importance should then be put on valuing all additional optionalities provided by additional physical assets. The following example is based on a trader serving the soybean market in Qingdao; he has one export elevator in the USG and the network of country elevators in the previous section that feed the USG location (listed in Table A2). The trader is currently contracting 5 million bushels (or 50%) to consumers in Qingdao. This contracting means that the trader has effectively contracted 5 million bushel to the export elevator from the country elevator network (12% of the capacity). By contracting 12% for the country elevator network, only 1% of the total network value is foregone. The current network then has a total value of $898 million ($203 million for the country elevators and $695 million for the export elevator).

The trader is considering the addition of an export elevator in either Paranaguá or the PNW. Contracting is to be held constant at 50% of capacity, and the total contracted amount increases to 10 million bushels.

Addition of Paranaguá

The commodity trader can add Paranaguá, create a network of export elevators (because there are now two elevators), and increase the export-elevator network's value from $695 million to $1.42 billion (an increase of $724 million). With further vertical integration to the country elevators in Brazil and the 5 million bushels contracted to the export elevator (needed to contract 10 million bushels in Qingdao), the network of country elevators adds between $377 and $373 million to the net present value. The trader already owns a network of country elevators in the United States that serve as the export elevator in the USG and is valued at $205 million. This complete vertical integration to Brazil would create a network with a net present value of $2.00 billion (an increase of $1.10 billion).

Addition of the Pacific Northwest

Vertically integrating to Paranaguá opens further integration to the country elevators in Brazil. Adding the PNW export elevator does not dictate this second step because the trader already has a network of country elevators in the United States, where 7 of 21 country elevators have the optionality to ship to the PNW. This optionality is, however, not exploited in the current network because the trader has no export elevator there. To value the addition of the PNW elevator, the embedded real option for the country elevators located in Ayr, Finley, Jamestown, Beatrice, Dorchester, Edison, and Maywood must be valued (the option to alternate the destination market). The optionality to switch the destination market has the same properties as the option to switch origin locations.

Adding the PNW export elevator increases the network of export elevators from $695 million to $1.61 billion (an increase of $915 million). If the commodity trader adds the PNW location, the soybeans needed at this additional export elevator are effectively pulled from the pre-existing network in the United States, therefore increasing the amount contracted in this network to 10 million bushels (24%). Adding the PNW export elevator, and therefore taking advantage of the embedded option to ship through the PNW market, increases the country-elevator network's value from $205 million to $267 million. This increase values the option to alternate shipping routes (PNW or USG) at $62 million for the 7 locations. Compared to the case that only has the Gulf as a destination market, the optimal contracting threshold increases from the 5% to 10% contracting level, and the excessive contracting threshold is reached at the 90%

contracting level instead of at the 71% contracting level (Figure 5.18). These favorable changes are the result of the additional flexibility.

By integrating the PNW export elevator to the network and utilizing the pre-existing network of country elevators to feed it, the contracted burden on the country-elevator network is increased from 12% to 24%. By contracting 24% in the country-elevator network, the trader foregoes 2% of the total network value (compared to no contracting). The network of country elevators is, therefore, worth $263 million. For the given trader, which is an increase of $58 million from the original $205 million. Adding the PNW export elevator, therefore, gives a total net present value of $1.87 billion (an increase of $975 million).

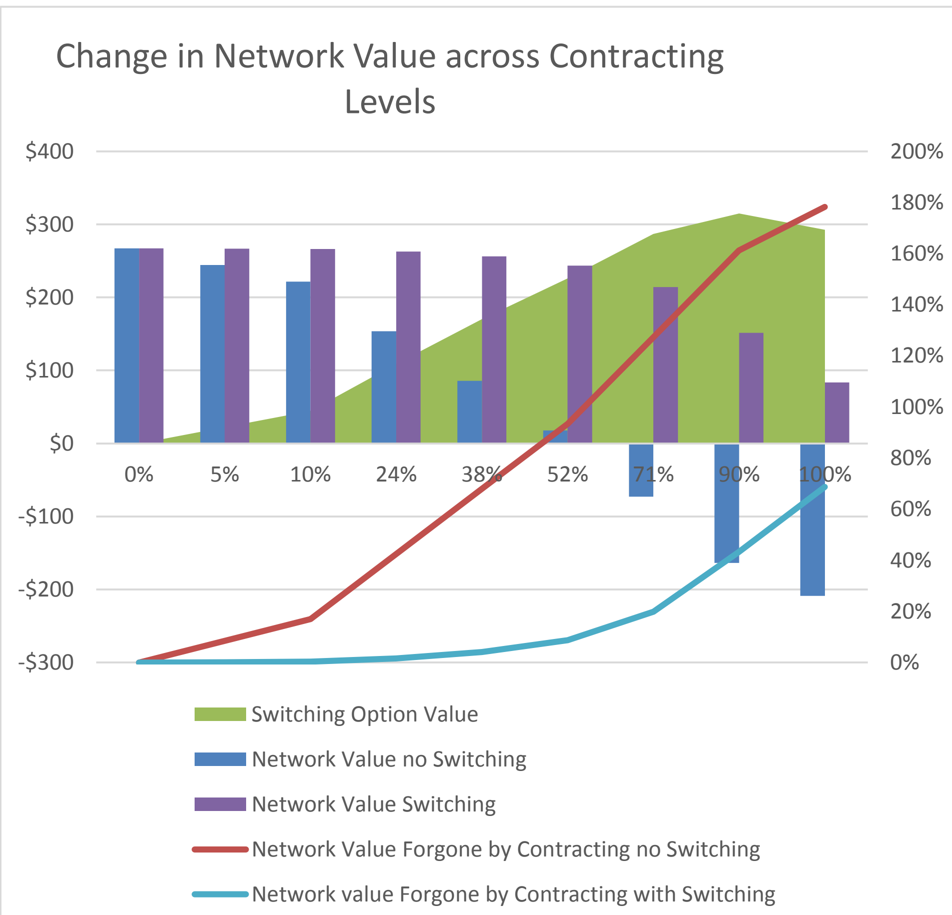

Figure 5.18. Network Behavior across Contracting Levels for the USG and PNW Network

PNW vs. Paranaguá

Traders should decide which elevator to acquire based upon the increased net present value and the amount they have to pay for the given increase. If we assume that an export elevator in the PNW and Paranaguá has the same price, the trader would have to purchase the 8 country elevators in Brazil for $130 million ($16.25 million each) to be indifferent between the strategies. This trader should, therefore, decide based on the price at which country elevators in Brazil can be acquired. Purchasing the PNW elevator increases the net present value by $975 million. Purchasing the Paranaguá export elevator results in an increase of $724 million ($1.10 billion if the country elevators are also purchased). These net present values means that the trader is better off purchasing the PNW export elevator if there are no plans of purchasing Brazilian country elevators (assuming the export elevator can be purchased for the same price). The trader is better off purchasing the Paranaguá export elevator if the network of Brazilian country elevators can be purchased for less than $130 million.

Option to Cease and Resume Operation

The focus of this thesis is to value the optionality to switch origins. Switching-option values are determined by profit distributions at individual elevators and the correlations between the locations. The flexibility to alternate origin locations only has a value when an imperfect management is introduced through the commitment of a certain amount of total capacity. This contracting removes the flexibility to not ship any grain whenever the market is unfavorable for the given trader. Traders limiting this flexibility, due to the utility received from contracting, forgoes the optionality to cease operations (close the elevator). Traders closing elevators incur a shutdown cost and a startup cost whenever operation is resumed. By paying this cost, the grain trader does not have to pay the fixed costs for running the elevator because workers are fired, etc.

The value of the option to close varies widely based on the probability of losses across the elevators.

Shutting Down Export Elevators

Traders contracting in the export-elevator network forego the optionality to shut down, which has a net present value of $996 thousand (Figure 5.19). The value of the option to close ranges between $0 and $130 million for the entire network. This optionality accounts for less than 0.1% of the total net present value. However, the limited flexibility increases the risk by decreasing the minimum profit from $140 million to -$15 million. The 5% value at risk decreases from a profit of $1.4 billion in the case with the flexibility to shut down, to $1.35 million when the flexibility is removed. This reduction might be considered acceptable, however, the reduced minimum profit is substantial. These numbers will change as the fixed operating costs, startup costs, and shutdown costs change (currently assumed to be $10 million to shut down/resume operation and $1 million for the monthly fixed costs during operation).

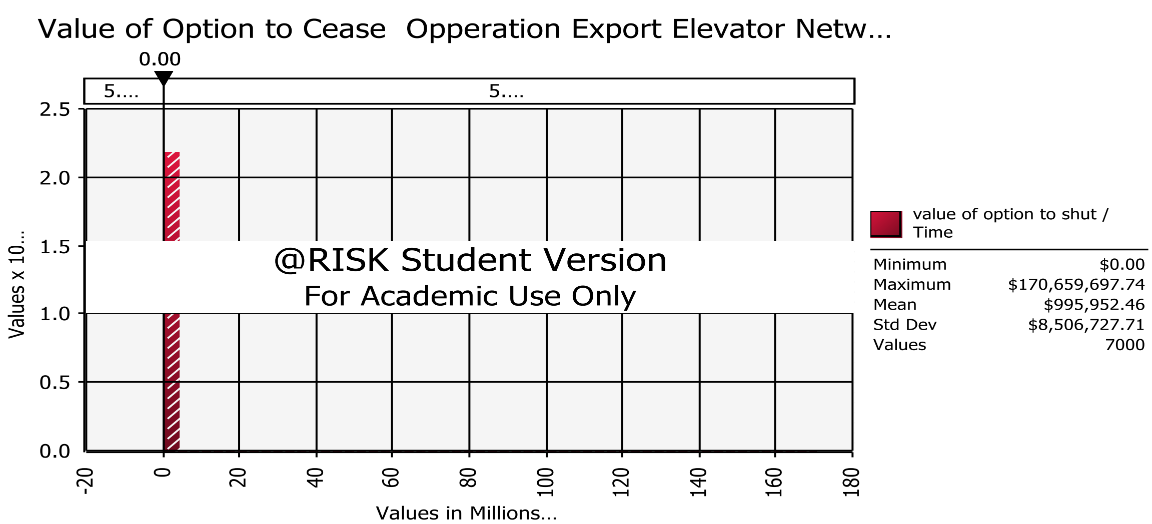

Figure 5.19. Value for the Option to Cease Operating the Export-Elevator Network

Shutting Down the Country Elevators

The value foregone by removing the flexibility to cease operation for country elevators is significantly higher than the value of the option for the export-elevator network. This magnification of value stems from the higher probability of losses. For the export elevators, this optionality effectively contributes less than 1% of the total net present value; for the country elevators serving the Gulf export elevator, this optionality has a value of $147 million (representing 41% of the total value; Figure 5.20). The distributions for the net present value across the two scenarios are displayed in Figure 5.21. This optionality to cease operation is likely overestimated because, in reality, these elevators could serve local markets when the USG market is unprofitable.

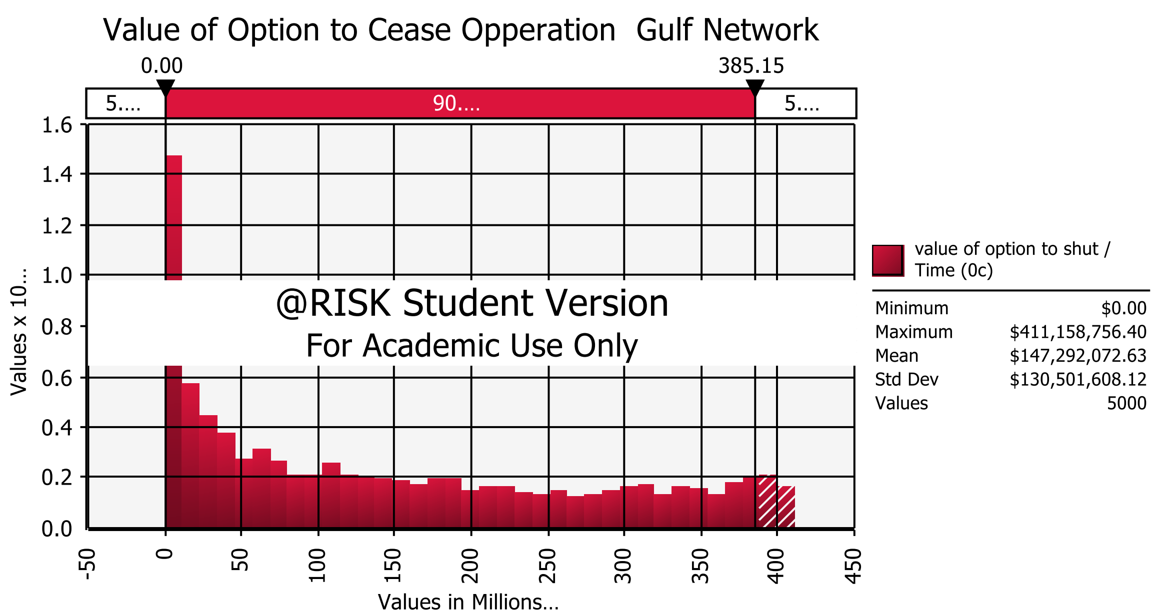

Figure 5.20. Value of Optionality to Shut Down the USG Network

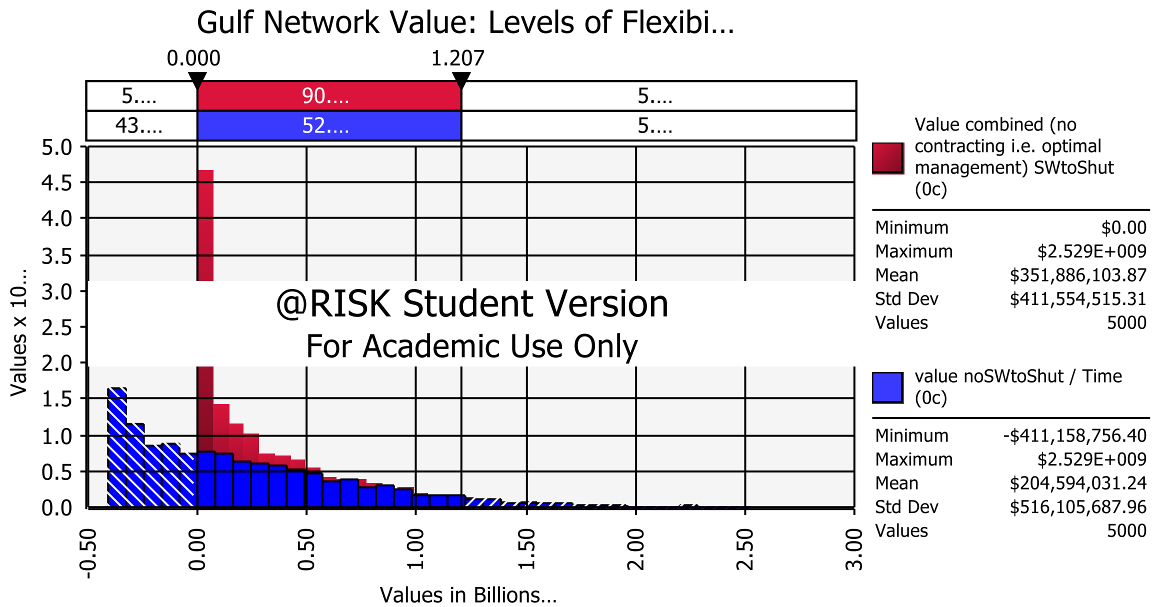

Figure 5.21. Net Present Value for the USG Network with/without the Flexibility to Close

Discount Rates

All the above cases are conducted with a 6% discount rate. To illustrate the effect of changing discount rates (cost of capital), a sensitivity analysis has been conducted with a 5%, 10%, 15%, and 20% rate for the export-elevator network. The 10% discount rate is generally considered to be the weighted adjusted cost of capital for privately held grain firms. The network value decreases between \$0.9 and \$0.4 billion with each increase. The results are summarized in Table 5.10.

Table 5.10. Effect of Increasing the Discount Rate

Discount Rate	5%	10%	15%	20%
Mean Value Network no Switching Option	$4824	$3883	$3192	$2675
Mean Value with Switching Option	$4910	$3952	$3248	$2722

CHAPTER 6. SUMMARY AND CONCLUSION

Commodity trading firms face an uncertain and changing future. Financial institutions and data-subscription services are eating away some of the advantages traditionally belonging to large trading firms. From the beginning of commodity trading, large firms generally had two major advantages (or economies of scale) (Caves, 1977). The first advantage, the intangible economies of scale, used to be knowledge. In the early days of international trade, companies with knowledge about the sea routes to origin markets captured the greatest profits. As time evolved, information became abundant. Shipping routes are no longer secret, and commodity firms are struggling to keep price data to themselves. Previously, firms that actively engaged in physical trade had the upper hand in the financial markets as well; this trend is rapidly changing as more trade is moving to algorithms and computers. Information becomes more transparent and, therefore, harder to control. As a result, protecting the second competitive advantage becomes far more important.

The second advantage, the tangible economies of scale, consists of physical assets and capital, can be protected by building vast networks across geographical regions, and effectively control some parts of the trade flow while hindering new entrants. To protect this advantage, commodity traders seek acquisition targets. Meersman, Reichtsteiner, and Sharp (2012) predict levels for mergers and acquisitions that were formerly unheard of. Trading firms have historically started as asset-light traders, i.e., no physical assets. These traders generally have low risks but also have low profit margins. As trading firms mature, they often seek to vertically integrate in the value chain. This integration leads not only to a far higher profit margin, but also to higher exposure to cyclical trends for commodity prices which, again, affect risk profiles. This thesis focuses on asset-medium traders (or asset-light traders seeking to become asset medium) and the optionality embedded in their networks.

By looking at recent takeovers in the grain industry, it is clear that international commodity firms seek to protect this advantage. For example, when ADM acquired GrainCorp, the following official statements were made: “GrainCorp would make an excellent addition to ADM’s global network, with a geographic footprint and grain handling, marketing and processing operations that complement our existing assets,” and “GrainCorp provides a strong origination platform that adds to our geographic diversity” (ADM, 2013). Similar statements were made when Glencore acquired Viterra: “The acquisition will give Glencore critical mass in the key grain markets of North America, as well as expanding Glencore’s existing operations in Australia,” and “Viterra’s first class assets in grain logistics and processing, with Glencore’s global marketing capability, Glencore has the opportunity to become a true leader across the sector” (Viterra, 2012). Each acquisition was completed at premiums around 50%.

Valuing the Optionality

Traditional discounted cash flow tends to undervalue projects with continuous decision making, which can lead trading firms to miss assets that appear overvalued but, in reality, could have been a great addition to their existing networks. Arbitrage is often viewed as risk free, with no requirements of initial capital. This view will, in many cases, not apply to the commodity trade as physical assets, and large amounts of capital are often needed (Shleifer & Vishny, 1997). Transfer costs should equal the difference in price between the origin market and the destination market in the long run, however, there are clearly arbitrage profits available in the short run. The profit opportunities vary across markets. Country elevators generally see lower profit probabilities relative to the export elevators.

Gaining Control of Trade Flows

Vertical integration, which occurs when one firm owns more than one stage of production, can be used to realize grater economic value because larger stretches of the value chain are controlled. This integration helps traders control who can access depressed prices in certain regions and helps maintain their advantage. A major factor contributing to the eagerness to acquire additional assets is the large uncertainty faced by traders in the current market.

Taleb (2008) argues that the impact of Black-Swan events, events that disrupt the marketplace, is steadily increasing. PricewaterhouseCoopers (2011) shows how these events seem to occur at a higher frequency. By definition, a trader cannot predict these events.

Diversified and well-managed networks can provide great value in these scenarios because the trader can pull supplies from markets where the price is severely depressed or can ship to markets where prices have increased. Even though Black-Swan events can provide large spatial-arbitrage profits at uncertain intervals, the large value driver for geographically diversified networks is the differences in seasonality between the markets. These seasonal variations can be caused by logistic congestion, different harvest times, and a lack of storage. Geographically differing prices can be viewed as market inefficiencies. The model does not seek to evaluate the origin of these price differences, but the effect that they have on physical assets and their valuation in the trading industry. More specifically, the value of flexibility embedded in networks. Flexibility which allows traders to take advantage of these price differences.

Real Options

Real options allow for the valuation of risk, the creation of strategies, and the generation of ideas about how to position your firm to best take advantage of the market (Mun, 2010). ROA allows for flexible management strategies under uncertainty. It is important to remember that physical assets have revenues and cash flows as standalone assets, but buy using real options, one can value the flexibilities associated with a purchase. The commodity trader seeks to value the right to originate grains from a cheaper location (by switching the origination needs there when the market is favorable). He would correspondingly acquire the option if the cost of the physical asset is outweighed by savings provided by the new optionality.

To take advantage of the switching option, a trader must first have a management imperfection that the embedded flexibility can neutralize. In the model, this imperfection is created by contracting parts of production. For example, Chapter 2 provided an example with a CHS trader. Here, the senior corn merchandizer had contracted a shipment of grain, however, the shuttle train got blocked by a blizzard; this situation would have resulted in a large loss because the trader would have been forced to purchase the grain from someone else and then deliver it. However, thanks to the vast network of shuttle trains that CHS controls, the company could simply re-route a train going in another direction, therefore avoiding the loss. Without this contractual obligation, the trader could simply have waited and sold the grain whenever it would have been profitable. It is assumed that traders see a value in contracting. In CHS' case, this contracting could have led to a loss, however, because CHS utilized the embedded flexibility in the network, this loss was effectively eliminated.

The Switching Option

Potential switching between markets can occur at any given point in time and is, therefore, regarded as the American style. Because the option essentially resets itself after each switch, the commodity trader buys a series of switching options that can be utilized to procure cheaper grain at any given point and repetitively until the physical asset's life period is over. The physical asset's price is essentially the option premium. Commodity traders should, therefore, seek to buy undervalued options. The model can provide an exact value for an additional location, both as a standalone asset and as part of the network. The commodity trader should seek to purchase the highest net present value possible for the least amount of money. If we assume two grain elevators, one would provide an additional net present value of $30 million (elevator 1) in the current network while the other only provides $10 million (elevator 2). The trader should try to acquire these elevators based on the most net present value purchased per dollar, not on the overall net present value. Let us assume elevator 1 is for sale for $29 million while the other is available for $8 million. Elevator 2 is clearly the better purchase because you get $2 million in net present value contrary to $1 million.

Results and Properties of the Switching Options

The seasonal profit opportunity, and the correlation between them dictates the switching option's value. These stochastic variables are represented by normal distributions based on the historical mean and standard deviation for each month.

The base case, where a trader manages the network connecting Brazil, the Ukraine, and the United States to China, provided valuable insight about switching options. The network could contract 0%, 25%, 50%, or 100%. Individually managed, the network decreased in value from $4.70 billion to $4.61 billion when one-quarter of the capacity was contracted, implying that the traders should only contract if contracting provides $89 million or more in benefits. The largest effect was, however, seen for the worst-possible outcome; the minimum net present value shrank by $1.5 billion per additional quarter of capacity contracted. If the network engaged in switching and was managed as one, the adverse move in the minimum value decreased drastically. The switching option represented a 4% increase in the mean value when 75% of the capacity was contracted.

In the second case, the probability of profit for each of the export elevators was manipulated downwards. This manipulation resulted in a higher relative and absolute value for the switching option. The switching option's part of the total net present value increased from 4% to 32% with the 75% contracting level. Higher correlations affected the option value in a similar manner; with a 50% increase in correlations, the network value decreased by 1.7%, which was fully captured in the reduction for the switching option (8.7%). This effect was magnified as more capacity was contracted. The switching option even had value when correlations were perfect across all markets.

By simulating the Brazilian country-elevator market, the model proved the existence of an excessive contracting threshold where the switching option starts to decrease in value (in absolute terms). For the given network, this threshold was found around the 63% contracting level. The existence of an optimal contracting threshold was also shown, indicating that the flexibility to switch can compensate for a certain level of contracting without decreasing the mean value. All commodity traders who receive a benefit from contracting should always contract up to this threshold. For the given network, this threshold was reached at 13% contracting.

Switching options obtain their value from creating flexibility. The value of this flexibility varies with correlations and the likelihood of negative profits:

- Increasing the probability of negative profits increases the switching option's value (both in absolute and percentage terms)
- Increasing correlations between spatial profit opportunities (increasing market efficiency) decreases the switching option's value.

Implications and Contributions to the Literature

Switching options related to international grain trade have received limited amounts of analysis. The major implications from the thesis can be divided into three categories. First, it shows the existence of switching options in the grain trade, providing an understanding about what drives the option value and which conditions must be met for it to have a value. The thesis shows how imperfections create the given option value as well as how correlations and profit distributions affect the value. The model has identified an optimal contracting threshold where commodity traders can find undiscovered utility. The identification of an excessive contracting threshold shows how large imperfections in managerial flexibility (through contracting), reduces the value of the switching option and the total network. These thresholds can help commodity traders discover if they are under or overly locked in contracts. Additionally, the lack of a correlation between several markets indicates that the international grain market is less than efficient. Interestingly, the domestic markets, both in Brazil and the United States, display relatively high correlations. However, the market between the export elevators and the destination market displays low correlations.

The second category of contributions can be seen as an aid for commodity traders' (both selling and purchasing) physical facilities in finding a fair price. Traders seeking to sell physical assets can see the added net present value of their assets as part of the purchaser's network and can then better assess what is a fair bid. The model provides traders seeking acquisitions with a methodology to value the physical asset, including the embedded optionalities (not detected by the discounted cash flow method). Traders can use the model as a tool to identify the strategy that lets them purchase the highest net present value per dollar.

The third, and maybe most important, implication is an explanation about why the international grain trade is dominated by a few large, multinational companies. The vast synergy effects (and economies of scale) provided by large, geographically diverse networks in inefficient markets can likely contribute to explaining the success of Cargill, ADM, and CHS. If an independent trader operates one elevator, the value might be $10 million, however, as part of a diversified and vertically integrated network, the value might increase by 2-32%, depending on the correlations and profit distributions. In either case, the increased value from the optionality (as part of a network) enables the large commodity firms to consistently outbid smaller traders in the hunt for physical assets and the control of trade flows. Assume a trader operates one elevator with a net present value of $10 million. A large trading firm might receive a net present value of $12 million. Clearly, the smaller trader would sell at $11 million because that sale increases the net present value, and the large trading firm would buy.

The thesis provides a methodology for trading firms to more accurately value physical assets. Valuation methods do not account for the embedded optionality, consistently undervaluing the asset, because the flexibility is not considered. The methodology in this thesis provides means to more accurately value the networks of physical assets and the individual assets included in the network.

Limitations

In the model, country elevators in Brazil and the United States can only ship soybeans to the export elevators. In reality, these country elevators might have more marketing flexibility. For example, during temporarily depressed prices at the export elevator, local markets can be served. Additionally, many elevators handle more than one commodity. At a point where no spatial arbitrage exists for soybeans, there could be opportunities for corn and wheat. Further, elevators generally have the opportunity to purchase a commodity when prices are perceived to be low and to store the commodity until a later point in time. Not accounting for these factors could pose as a limitation for the country elevators' actual value.

The model assumes constant correlations for the entire 10-year valuation period. This assumption could be a limitation. The American market has been an international player for an extensive time period, and the correlations could be assumed to be relatively stable. However, correlations with the Ukrainian market could be expected to increase with market maturity (as the market becomes more efficient).

Suggestions for Future Research

A valuable approach for future research would be the first set of limitations. First, adding the option to store the commodity should be included. This inclusion would value the flexibility embedded in commodity firms' storage space. Second, because many elevators have the potential to handle other commodities, further research should be conducted with the option values for other commodities. Thereafter, the inclusion of an option to switch which commodity the elevator handles should be included in the literature. These two additions would most likely create a very accurate estimate for elevator values.

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APPENDIX

Table A1. Correlations between Profit Opportunities Export Elevators Shipping to Qingdao, China

Elevator	Paranaguá	Black Sea	PNW	USG
Paranaguá	1.00			
Black Sea	0.35	1.00		
PNW	0.76	0.35	1.00	
USG	0.80	0.46	0.96	1.00

Table A2. Correlations between Profit Opportunities Country Elevators Shipping to the USG

Elevator	Bayard	Creston	Albany	Mound City	Nauvoo	Pekin	Aurora	Evansville	Jeffersonville	Mount Vernon	Breckenridge	Jasper	Ayr	Finley	Jamestown	Beatrice	Dorchester	Edison	Maywood	Cincinnati Bunge	Cincinnati Cargill
Bayard	1.00																				
Creston	0.89	1.00																			
Albany	0.67	0.71	1.00																		
Mound City	0.72	0.74	0.81	1.00																	
Nauvoo	0.73	0.77	0.81	0.71	1.00																
Pekin	0.73	0.80	0.84	0.84	0.84	1.00															
Aurora	0.74	0.81	0.80	0.83	0.81	0.91	1.00														
Evansville	0.69	0.77	0.85	0.86	0.81	0.93	0.91	1.00													
Jeffersonville	0.74	0.80	0.82	0.87	0.82	0.91	0.95	0.92	1.00												
Mount Vernon	0.69	0.74	0.78	0.78	0.76	0.85	0.84	0.85	0.85	1.00											
Breckenridge	0.84	0.91	0.68	0.76	0.70	0.79	0.80	0.78	0.78	0.71	1.00										
Jasper	0.88	0.87	0.55	0.64	0.65	0.67	0.71	0.61	0.68	0.63	0.84	1.00									
Ayr	0.81	0.88	0.70	0.78	0.69	0.79	0.78	0.79	0.78	0.70	0.95	0.78	1.00								
Finley	0.77	0.86	0.71	0.79	0.70	0.79	0.79	0.82	0.79	0.75	0.94	0.76	0.95	1.00							
Jamestown	0.62	0.67	0.47	0.62	0.49	0.54	0.55	0.54	0.54	0.58	0.74	0.63	0.69	0.73	1.00						
Beatrice	0.88	0.89	0.64	0.72	0.69	0.71	0.74	0.69	0.73	0.65	0.86	0.83	0.87	0.82	0.61	1.00					
Dorchester	0.85	0.93	0.66	0.68	0.71	0.74	0.75	0.72	0.74	0.65	0.90	0.82	0.90	0.85	0.61	0.94	1.00				
Edison	0.88	0.91	0.68	0.73	0.71	0.76	0.76	0.76	0.75	0.72	0.93	0.85	0.91	0.91	0.70	0.89	0.91	1.00			
Maywood	0.87	0.90	0.67	0.74	0.71	0.74	0.75	0.75	0.74	0.72	0.91	0.85	0.90	0.91	0.71	0.90	0.91	0.99	1.00		
Cincinnati Bunge	0.76	0.81	0.83	0.81	0.82	0.86	0.84	0.86	0.86	0.86	0.73	0.69	0.74	0.74	0.54	0.72	0.73	0.74	0.74	1.00	
Cincinnati Cargill	0.74	0.81	0.80	0.86	0.80	0.91	0.89	0.90	0.91	0.81	0.79	0.72	0.78	0.80	0.57	0.74	0.75	0.78	0.76	0.83	1.00

Table A3. Correlations between Profit Opportunities Country Elevators Shipping to the USG and the PNW

Elevator	Bayard	Creston	Albany	Mound City	Nauvoo	Pekin	Aurora	Evansville	Jeffersonville	Mount Vernon	Breckenridge	Jasper	Ayr	Finley	Jamestown	Beatrice	Dorchester	Edison	Maywood	Cincinnati Bunge	Cincinnati Cargill
Bayard	1.00																				
Creston	0.89	1.00																			
Albany	0.67	0.71	1.00																		
Mound City	0.72	0.74	0.81	1.00																	
Nauvoo	0.73	0.77	0.81	0.71	1.00																
Pekin	0.73	0.80	0.84	0.84	0.84	1.00															
Aurora	0.74	0.81	0.80	0.83	0.81	0.91	1.00														
Evansville	0.69	0.77	0.85	0.86	0.81	0.93	0.91	1.00													
Jeffersonville	0.74	0.80	0.82	0.87	0.82	0.91	0.95	0.92	1.00												
Mount Vernon	0.69	0.74	0.78	0.78	0.76	0.85	0.84	0.85	0.85	1.00											
Breckenridge	0.84	0.91	0.68	0.76	0.70	0.79	0.80	0.78	0.78	0.71	1.00										
Jasper	0.87	0.86	0.57	0.63	0.66	0.66	0.70	0.60	0.67	0.63	0.82	1.00									
Ayr	0.78	0.85	0.69	0.75	0.68	0.75	0.74	0.75	0.73	0.69	0.93	0.75	1.00								
Finley	0.72	0.82	0.67	0.75	0.66	0.73	0.72	0.76	0.72	0.72	0.91	0.72	0.93	1.00							
Jamestown	0.56	0.60	0.43	0.57	0.46	0.48	0.49	0.48	0.47	0.54	0.68	0.58	0.63	0.68	1.00						
Beatrice	0.88	0.88	0.72	0.75	0.77	0.78	0.79	0.76	0.79	0.74	0.81	0.80	0.84	0.75	0.53	1.00					
Dorchester	0.84	0.92	0.73	0.70	0.79	0.79	0.79	0.77	0.78	0.73	0.85	0.78	0.86	0.79	0.52	0.95	1.00				
Edison	0.86	0.89	0.73	0.74	0.76	0.79	0.77	0.79	0.77	0.77	0.89	0.80	0.87	0.87	0.63	0.87	0.89	1.00			
Maywood	0.87	0.90	0.67	0.74	0.71	0.74	0.75	0.75	0.74	0.72	0.91	0.81	0.88	0.88	0.65	0.86	0.88	0.98	1.00		
Cincinnati Bunge	0.76	0.81	0.83	0.81	0.82	0.86	0.84	0.86	0.86	0.86	0.73	0.69	0.73	0.70	0.50	0.80	0.80	0.79	0.74	1.00	
Cincinnati Cargill	0.74	0.81	0.80	0.86	0.80	0.91	0.89	0.90	0.91	0.81	0.79	0.72	0.75	0.76	0.52	0.78	0.78	0.79	0.76	0.83	1.00

Table A4. Correlations between Profit Opportunities Country Elevators Shipping to Paranaguá, Brazil

Elevator	Barreiras, Bahia	Rio Verde, Goias	Rondonopolis, Mato Grosso	Sorriso, Mato Grosso	Triangulo Mineiro, Minas Gerais	Ponta Grossa, Parana	Ijui, Rio Grande do Sul	Passo Fundo, Rio Grande do Sul	Sorocabana, Sao Paulo
Barreiras, Bahia	1.00								
Rio Verde, Goias	0.78	1.00							
Rondonopolis, Mato Grosso	0.82	0.68	1.00						
Sorriso, Mato Grosso	0.80	0.71	0.94	1.00					
Triangulo Mineiro, Minas Gerais	0.83	0.82	0.77	0.77	1.00				
Ponta Grossa, Parana	0.45	0.73	0.42	0.43	0.65	1.00			
Ijui, Rio Grande do Sul	0.62	0.61	0.47	0.43	0.63	0.71	1.00		
Passo Fundo, Rio Grande do Sul	0.58	0.61	0.47	0.43	0.61	0.73	0.98	1.00	0.57
Sorocabana, Sao Paulo	0.39	0.61	0.47	0.54	0.41	0.51	0.51	0.57	1.00

Table A5. Correlations between Market Prices Export Elevators Shipping to Qingdao, China

Elevator	Paranaguá	Black Sea	PNW	USG
Paranaguá	1			
Black Sea	0.54	1		
PNW	0.93	0.50	1	
USG	0.94	0.54	0.99	1

Table A6. Correlations between Market Prices Country Elevators Shipping to the USG

Elevator	Bayard	Creston	Albany	Mound City	Nauvoo	Pekin	Aurora	Evansville	Jeffersonville	Mount Vernon	Breckenridge	Jasper	Ayr	Finley	Jamestown	Beatrice	Dorchester	Edison	Maywood	Cincinnati Bunge	Cincinnati Cargill
Bayard	1.00																				
Creston	1.00	1.00																			
Albany	0.99	0.99	1.00																		
Mound City	1.00	1.00	1.00	1.00																	
Nauvoo	1.00	1.00	1.00	1.00	1.00																
Pekin	1.00	1.00	1.00	1.00	1.00	1.00															
Aurora	1.00	1.00	0.99	1.00	1.00	1.00	1.00														
Evansville	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00													
Jeffersonville	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00												
Mount Vernon	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00											
Breckenridge	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00										
Jasper	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00									
Ayr	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00								
Finley	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00							
Jamestown	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	1.00	0.99	1.00	1.00	1.00						
Beatrice	1.00	1.00	1.00	0.99	1.00	1.00	0.99	0.99	0.99	1.00	1.00	1.00	0.99	0.99	0.99	1.00					
Dorchester	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00				
Edison	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00			
Maywood	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		
Cincinnati Bunge	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00	1.00	1.00	1.00	
Cincinnati Cargill	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00	1.00	1.00	1.00	1.00

Table A7. Correlations between Market Prices Country Elevators Shipping to the USG and/or the PNW

Elevator	Bayard	Creston	Albany	Mound City	Nauvoo	Pekin	Aurora	Evansville	Jeffersonville	Mount Vernon	Breckenridge	Jasper	Ayr	Finley	Jamestown	Beatrice	Dorchester	Edison	Maywood	Cincinnati Bunge	Cincinnati Cargill
Bayard	1.00																				
Creston	1.00	1.00																			
Albany	1.00	1.00	1.00																		
Mound City	0.99	1.00	1.00	1.00																	
Nauvoo	1.00	1.00	1.00	1.00	1.00																
Pekin	1.00	1.00	1.00	1.00	1.00	1.00															
Aurora	1.00	1.00	1.00	1.00	1.00	1.00	1.00														
Evansville	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00													
Jeffersonville	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00												
Mount Vernon	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00											
Breckenridge	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00										
Jasper	1.00	1.00	0.99	0.99	1.00	1.00	1.00	0.99	1.00	0.99	1.00	1.00									
Ayr	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00								
Finley	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00							
Jamestown	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	1.00						
Beatrice	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00					
Dorchester	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00				
Edison	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00			
Maywood	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00		
Cincinnati Bunge	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	
Cincinnati Cargill	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00

Table A8. Correlations between Market Prices Country Elevators Shipping to Paranaguá, Brazil

Elevator	Barreiras, Bahia	Rio Verde, Goias	Rondonopolis, Mato Grosso	Sorriso, Mato Grosso	Triangulo Mineiro, Minas Gerais	Ponta Grossa, Parana	Ijui, Rio Grande do Sul	Passo Fundo, Rio Grande do Sul	Sorocabana, Sao Paulo
Barreiras, Bahia	1.00								
Rio Verde, Goias	0.99	1.00							
Rondonopolis, Mato Grosso	0.99	0.99	1.00						
Sorriso, Mato Grosso	0.99	0.99	0.99	1.00					
Triangulo Mineiro, Minas Gerais	0.99	0.99	0.99	0.99	1.00				
Ponta Grossa, Parana	0.99	0.99	0.99	0.99	0.99	1.00			
Ijui, Rio Grande do Sul	0.99	0.99	0.98	0.98	0.99	0.99	1.00		
Passo Fundo, Rio Grande do Sul	0.99	0.99	0.98	0.98	0.99	0.99	1.00	1.00	
Sorocabana, Sao Paulo	0.99	0.99	0.99	0.99	0.98	0.99	0.99	0.99	1.00

Table A9. Random Variables representing Seasonal Profitability Distributions for Export Elevators Shipping to Qingdao, China

Elevator	Distribution	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Parangua	Normal(μ,σ)	(1.49,0.58)	(1.79,0.59)	(1.63,0.85)	(1.6,1.14)	(0.63,0.71)	(0.41,0.49)	(-0.06,0.68)	(-0.18,0.83)	(0.46,0.79)	(1.28,0.38)	(1.4,0.9)	(1.47,0.98)
Black Sea	Normal(μ,σ)	(3.87,2.18)	(1.88,1.18)	(1.42,0.93)	(2.23,1.17)	(0.93,0.91)	(0.72,1.49)	(1.15,2.76)	(-0.48,2.59)	(2.4,0.92)	(3.12,0.86)	(3.18,1.13)	(2.99,1.3)
PNW	Normal(μ,σ)	(1.7,0.63)	(1.61,0.5)	(1.14,0.57)	(1.07,0.49)	(0.66,0.52)	(0.7,0.4)	(0.18,0.62)	(0.51,0.35)	(1.72,0.34)	(2.09,0.35)	(2.25,0.61)	(1.8,0.66)
USG	Normal(μ,σ)	(1.43,0.64)	(1.36,0.55)	(0.94,0.68)	(0.83,0.65)	(0.35,0.68)	(0.16,0.44)	(-0.44,0.51)	(-0.12,0.41)	(1.29,0.37)	(1.73,0.45)	(1.98,0.75)	(1.51,0.75)

Table A10. Random Variables representing Seasonal Profitability Distributions for Country Elevators Shipping to USG

Elevator	Distribution	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bayard	Normal(μ,σ)	(0.17,0.12)	(0.25,0.21)	(-0.02,0.11)	(0,0.18)	(-0.06,0.13)	(0,0.16)	(0.19,0.31)	(0.07,0.33)	(0.09,0.39)	(-0.01,0.22)	(-0.03,0.13)	(0.11,0.09)
Creston	Normal(μ,σ)	(0.15,0.16)	(0.14,0.13)	(-0.06,0.1)	(-0.06,0.14)	(-0.12,0.14)	(0.02,0.2)	(0.25,0.43)	(0.06,0.46)	(0.12,0.37)	(-0.03,0.2)	(-0.07,0.15)	(0.04,0.06)
Albany	Normal(μ,σ)	(1.14,0.2)	(1.21,0.27)	(0.91,0.18)	(0.88,0.31)	(0.85,0.23)	(0.91,0.3)	(1.11,0.3)	(0.99,0.44)	(1.02,0.55)	(0.97,0.31)	(0.94,0.23)	(1.09,0.2)
Mound City	Normal(μ,σ)	(0.2,0.25)	(0.18,0.26)	(0,0.14)	(0.07,0.09)	(0.12,0.21)	(0.11,0.13)	(0.3,0.43)	(0.27,0.44)	(0.12,0.44)	(-0.21,0.49)	(-0.22,0.41)	(0.13,0.18)
Nauvoo	Normal(μ,σ)	(0.13,0.14)	(0.19,0.09)	(0.11,0.16)	(0.19,0.08)	(0.19,0.1)	(0.21,0.13)	(0.45,0.33)	(0.42,0.46)	(0.32,0.4)	(0.19,0.12)	(0.1,0.08)	(0.05,0.16)
Pekin	Normal(μ,σ)	(0.16,0.15)	(0.19,0.09)	(0.14,0.08)	(0.18,0.06)	(0.21,0.1)	(0.18,0.09)	(0.36,0.39)	(0.25,0.39)	(0.25,0.33)	(0.07,0.07)	(-0.07,0.34)	(0.04,0.15)
Aurora	Normal(μ,σ)	(0.09,0.15)	(0.15,0.1)	(0.13,0.09)	(0.13,0.11)	(0.15,0.11)	(0.12,0.11)	(0.33,0.37)	(0.2,0.38)	(0.2,0.29)	(0.15,0.08)	(0.06,0.09)	(0.04,0.16)
Evansville	Normal(μ,σ)	(0.01,0.15)	(0.05,0.1)	(0.03,0.08)	(0.06,0.08)	(0.06,0.1)	(0.06,0.1)	(0.26,0.4)	(0.19,0.46)	(0.14,0.36)	(-0.01,0.07)	(-0.01,0.12)	(-0.07,0.18)
Jeffersonville	Normal(μ,σ)	(0.09,0.16)	(0.15,0.1)	(0.12,0.07)	(0.13,0.12)	(0.16,0.12)	(0.14,0.11)	(0.33,0.36)	(0.23,0.38)	(0.2,0.3)	(0.15,0.09)	(0.05,0.11)	(0.05,0.19)
Mount Vernon	Normal(μ,σ)	(-0.01,0.15)	(0.02,0.12)	(-0.05,0.09)	(-0.01,0.08)	(0.02,0.12)	(0.01,0.09)	(0.18,0.39)	(0.09,0.57)	(-0.06,0.29)	(-0.09,0.08)	(-0.07,0.08)	(-0.08,0.21)
Breckenridge	Normal(μ,σ)	(0.02,0.26)	(0,0.21)	(-0.1,0.15)	(-0.12,0.17)	(-0.14,0.14)	(-0.04,0.12)	(0.28,0.4)	(0.1,0.46)	(0.09,0.48)	(-0.14,0.28)	(-0.16,0.18)	(-0.11,0.15)
Jasper	Normal(μ,σ)	(0.07,0.21)	(0.08,0.19)	(-0.09,0.15)	(-0.12,0.2)	(-0.17,0.16)	(-0.03,0.28)	(0.18,0.32)	(0,0.38)	(-0.05,0.4)	(-0.06,0.24)	(-0.12,0.16)	(-0.02,0.12)
Ayr	Normal(μ,σ)	(0.01,0.23)	(0,0.22)	(-0.14,0.14)	(-0.08,0.2)	(-0.08,0.16)	(0.03,0.17)	(0.29,0.44)	(0.13,0.47)	(0.09,0.52)	(-0.13,0.32)	(-0.14,0.2)	(-0.1,0.15)
Finley	Normal(μ,σ)	(-0.04,0.2)	(-0.03,0.17)	(-0.14,0.13)	(-0.08,0.22)	(-0.07,0.18)	(0.08,0.16)	(0.35,0.5)	(0.25,0.7)	(0.04,0.52)	(-0.2,0.32)	(-0.18,0.2)	(-0.15,0.14)
Jamestown	Normal(μ,σ)	(0.04,0.24)	(0.03,0.2)	(-0.17,0.11)	(-0.03,0.14)	(-0.01,0.22)	(0.02,0.18)	(0.23,0.34)	(0.07,0.99)	(0.07,0.5)	(-0.17,0.28)	(-0.12,0.15)	(-0.08,0.14)
Beatrice	Normal(μ,σ)	(0.25,0.17)	(0.26,0.18)	(0.09,0.16)	(0.08,0.22)	(0.03,0.16)	(0.1,0.18)	(0.24,0.38)	(0.19,0.38)	(0.24,0.47)	(0.12,0.3)	(0.14,0.21)	(0.2,0.11)
Dorchester	Normal(μ,σ)	(0.19,0.17)	(0.22,0.19)	(0.08,0.15)	(0.03,0.24)	(-0.04,0.12)	(0.08,0.19)	(0.28,0.47)	(0.15,0.38)	(0.23,0.48)	(0.09,0.31)	(0.09,0.2)	(0.16,0.1)
Edison	Normal(μ,σ)	(0.21,0.11)	(0.25,0.16)	(0.11,0.16)	(0.18,0.25)	(0.13,0.12)	(0.19,0.18)	(0.44,0.51)	(0.31,0.47)	(0.25,0.5)	(0.08,0.29)	(0.12,0.16)	(0.14,0.07)
Maywood	Normal(μ,σ)	(0.27,0.11)	(0.31,0.17)	(0.17,0.2)	(0.24,0.26)	(0.19,0.17)	(0.25,0.21)	(0.49,0.53)	(0.36,0.53)	(0.31,0.52)	(0.15,0.31)	(0.18,0.19)	(0.2,0.09)
Cincinnati Bunge	Normal(μ,σ)	(0.2,0.15)	(0.24,0.11)	(0.13,0.16)	(0.19,0.09)	(0.19,0.24)	(0.25,0.26)	(0.43,0.38)	(0.26,0.46)	(0.26,0.29)	(0.25,0.4)	(0.18,0.1)	(0.17,0.17)
Cincinnati Cargill	Normal(μ,σ)	(0.08,0.15)	(0.14,0.09)	(0.08,0.07)	(0.11,0.1)	(0.15,0.12)	(0.18,0.18)	(0.32,0.36)	(0.25,0.44)	(0.26,0.39)	(0.12,0.08)	(0.04,0.08)	(0,0.16)

Table A11. Random Variables representing Seasonal Profitability Distributions for Country Elevators Shipping to USG and PNW

Elevator	Distribution	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bayard	Normal(μ,σ)	(0.17,0.12)	(0.25,0.21)	(-0.02,0.11)	(0,0.18)	(-0.06,0.13)	(0,0.16)	(0.19,0.31)	(0.07,0.33)	(0.09,0.39)	(-0.01,0.22)	(-0.03,0.13)	(0.11,0.09)
Creston	Normal(μ,σ)	(0.15,0.16)	(0.14,0.13)	(-0.06,0.1)	(-0.06,0.14)	(-0.12,0.14)	(0.02,0.2)	(0.25,0.43)	(0.06,0.46)	(0.12,0.37)	(-0.03,0.2)	(-0.07,0.15)	(0.04,0.06)
Albany	Normal(μ,σ)	(1.14,0.2)	(1.21,0.27)	(0.91,0.18)	(0.88,0.31)	(0.85,0.23)	(0.91,0.3)	(1.11,0.3)	(0.99,0.44)	(1.02,0.55)	(0.97,0.31)	(0.94,0.23)	(1.09,0.2)
Mound City	Normal(μ,σ)	(0.2,0.25)	(0.18,0.26)	(0,0.14)	(0.07,0.09)	(0.12,0.21)	(0.11,0.13)	(0.3,0.43)	(0.27,0.44)	(0.12,0.44)	(-0.21,0.49)	(-0.22,0.41)	(0.13,0.18)
Nauvoo	Normal(μ,σ)	(0.13,0.14)	(0.19,0.09)	(0.11,0.16)	(0.19,0.08)	(0.19,0.1)	(0.21,0.13)	(0.45,0.33)	(0.42,0.46)	(0.32,0.4)	(0.19,0.12)	(0.1,0.08)	(0.05,0.16)
Pekin	Normal(μ,σ)	(0.16,0.15)	(0.19,0.09)	(0.14,0.08)	(0.18,0.06)	(0.21,0.1)	(0.18,0.09)	(0.36,0.39)	(0.25,0.39)	(0.25,0.33)	(0.07,0.07)	(-0.07,0.34)	(0.04,0.15)
Aurora	Normal(μ,σ)	(0.09,0.15)	(0.15,0.1)	(0.13,0.09)	(0.13,0.11)	(0.15,0.11)	(0.12,0.11)	(0.33,0.37)	(0.2,0.38)	(0.2,0.29)	(0.15,0.08)	(0.06,0.09)	(0.04,0.16)
Evansville	Normal(μ,σ)	(0.01,0.15)	(0.05,0.1)	(0.03,0.08)	(0.06,0.08)	(0.06,0.1)	(0.06,0.1)	(0.26,0.4)	(0.19,0.46)	(0.14,0.36)	(-0.01,0.07)	(-0.01,0.12)	(-0.07,0.18)
Jeffersonville	Normal(μ,σ)	(0.09,0.16)	(0.15,0.1)	(0.12,0.07)	(0.13,0.12)	(0.16,0.12)	(0.14,0.11)	(0.33,0.36)	(0.23,0.38)	(0.2,0.3)	(0.15,0.09)	(0.05,0.11)	(0.05,0.19)
Mount Vernon	Normal(μ,σ)	(-0.01,0.15)	(0.02,0.12)	(-0.05,0.09)	(-0.01,0.08)	(0.02,0.12)	(0.01,0.09)	(0.18,0.39)	(0.09,0.57)	(-0.06,0.29)	(-0.09,0.08)	(-0.07,0.08)	(-0.08,0.21)
Breckenridge	Normal(μ,σ)	(0.02,0.26)	(0,0.21)	(-0.1,0.15)	(-0.12,0.17)	(-0.14,0.14)	(-0.04,0.12)	(0.28,0.4)	(0.1,0.46)	(0.09,0.48)	(-0.14,0.28)	(-0.16,0.18)	(-0.11,0.15)
Jasper	Normal(μ,σ)	(0.07,0.21)	(0.08,0.19)	(-0.09,0.15)	(-0.12,0.2)	(-0.17,0.16)	(-0.03,0.28)	(0.18,0.32)	(0,0.38)	(-0.05,0.4)	(-0.06,0.24)	(-0.12,0.16)	(-0.02,0.12)
Ayr	Normal(μ,σ)	(0.24,0.2)	(0.22,0.16)	(0.01,0.08)	(0.1,0.13)	(0.1,0.11)	(0.07,0.15)	(0.26,0.41)	(0.23,0.32)	(0.12,0.48)	(-0.06,0.17)	(0.04,0.14)	(0.1,0.08)
Finley	Normal(μ,σ)	(0.22,0.17)	(0.22,0.11)	(0.04,0.08)	(0.13,0.16)	(0.13,0.11)	(0.15,0.14)	(0.34,0.45)	(0.38,0.55)	(0.1,0.47)	(-0.09,0.16)	(0.03,0.12)	(0.09,0.06)
Jamestown	Normal(μ,σ)	(0.29,0.2)	(0.26,0.15)	(0,0.21)	(0.17,0.08)	(0.18,0.12)	(0.08,0.23)	(0.22,0.23)	(0.19,0.89)	(0.12,0.45)	(-0.09,0.13)	(0.08,0.1)	(0.14,0.11)
Beatrice	Normal(μ,σ)	(0.25,0.16)	(0.25,0.15)	(0.01,0.15)	(0.04,0.18)	(-0.02,0.13)	(-0.08,0.18)	(-0.03,0.36)	(0.05,0.23)	(0.02,0.35)	(-0.05,0.13)	(0.08,0.18)	(0.17,0.16)
Dorchester	Normal(μ,σ)	(0.19,0.15)	(0.21,0.15)	(0,0.13)	(0,0.2)	(-0.08,0.11)	(-0.11,0.2)	(0.02,0.46)	(0.01,0.23)	(0.01,0.37)	(-0.08,0.12)	(0.04,0.16)	(0.12,0.13)
Edison	Normal(μ,σ)	(0.24,0.09)	(0.28,0.12)	(0.07,0.12)	(0.19,0.18)	(0.12,0.04)	(0.04,0.17)	(0.21,0.47)	(0.21,0.31)	(0.07,0.38)	(-0.06,0.08)	(0.1,0.1)	(0.14,0.12)
Maywood	Normal(μ,σ)	(0.31,0.08)	(0.35,0.12)	(0.14,0.18)	(0.26,0.19)	(0.19,0.07)	(0.11,0.14)	(0.27,0.48)	(0.28,0.37)	(0.15,0.42)	(0.03,0.11)	(0.17,0.13)	(0.22,0.13)
Cincinnati Bunge	Normal(μ,σ)	(0.2,0.15)	(0.24,0.11)	(0.13,0.16)	(0.19,0.09)	(0.19,0.24)	(0.25,0.26)	(0.43,0.38)	(0.26,0.46)	(0.26,0.29)	(0.25,0.4)	(0.18,0.1)	(0.17,0.17)
Cincinnati Cargill	Normal(μ,σ)	(0.08,0.15)	(0.14,0.09)	(0.08,0.07)	(0.11,0.1)	(0.15,0.12)	(0.18,0.18)	(0.32,0.36)	(0.25,0.44)	(0.26,0.39)	(0.12,0.08)	(0.04,0.08)	(0,0.16)

Table A12. Random Variables representing Seasonal Profitability Distributions for Country Elevators Shipping to Paranaguá

Elevator	Distribution	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Barreiras, Bahia	Normal(μ,σ)	(-0.74,0.96)	(-0.94,0.41)	(-0.92,0.52)	(-1.1,0.51)	(-0.96,0.47)	(-0.69,0.55)	(-0.63,0.69)	(-0.68,0.75)	(-0.76,0.65)	(-0.83,0.54)	(-0.71,0.63)	(-0.88,0.71)
Rio Verde, Goias	Normal(μ,σ)	(0.11,0.66)	(-0.21,0.19)	(-0.12,0.36)	(0.04,0.42)	(0.18,0.32)	(0.35,0.38)	(0.39,0.46)	(0.34,0.48)	(0.26,0.5)	(0.03,0.31)	(0.04,0.42)	(-0.03,0.57)
Rondonopolis, Mato Grosso	Normal(μ,σ)	(0.23,0.7)	(0.09,0.31)	(-0.09,0.31)	(-0.19,0.32)	(-0.23,0.31)	(-0.16,0.36)	(-0.13,0.4)	(-0.2,0.46)	(-0.16,0.62)	(-0.36,0.48)	(-0.38,0.5)	(-0.24,0.38)
Sorriso, Mato Grosso	Normal(μ,σ)	(0.17,0.61)	(0.12,0.37)	(-0.01,0.36)	(-0.11,0.36)	(-0.14,0.3)	(-0.03,0.46)	(0.02,0.55)	(-0.11,0.52)	(-0.19,0.53)	(-0.35,0.51)	(-0.32,0.52)	(-0.25,0.48)
Triangulo Mineiro, Minas Gerais	Normal(μ,σ)	(0.3,0.68)	(0.03,0.13)	(-0.22,0.44)	(-0.28,0.51)	(-0.21,0.45)	(-0.03,0.48)	(0.01,0.57)	(0.02,0.65)	(-0.02,0.53)	(-0.12,0.54)	(0,0.57)	(0.07,0.66)
Ponta Grossa, Parana	Normal(μ,σ)	(0.85,0.55)	(0.52,0.24)	(0.49,0.26)	(0.5,0.36)	(0.63,0.41)	(0.87,0.53)	(1.1,0.76)	(1.02,0.69)	(0.95,0.75)	(0.77,0.23)	(0.71,0.35)	(0.62,0.44)
Rio Grande do Sul	Normal(μ,σ)	(0.43,0.66)	(0.19,0.42)	(0.19,0.31)	(-0.01,0.25)	(0.3,0.33)	(0.46,0.29)	(0.63,0.52)	(0.69,0.49)	(0.6,0.45)	(0.43,0.4)	(0.36,0.48)	(0.26,0.52)
Passo Fundo, Rio Grande do Sul	Normal(μ,σ)	(0.54,0.67)	(0.36,0.41)	(0.39,0.24)	(0.26,0.24)	(0.51,0.31)	(0.66,0.3)	(0.81,0.53)	(0.86,0.56)	(0.78,0.54)	(0.55,0.45)	(0.5,0.56)	(0.37,0.61)
Sorocabana, Sao Paulo	Normal(μ,σ)	(0.3,0.65)	(0.48,0.26)	(0.5,0.29)	(0.64,0.3)	(0.58,0.26)	(0.61,0.23)	(0.66,0.32)	(0.55,0.21)	(0.34,0.24)	(0.1,0.37)	(-0.01,0.57)	(-0.06,0.63)