BIDDING COMPETITION AND SUPPLY CHAIN RISK IN SOYBEAN EXPORTS

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Bidding Competition and Supply Chain Risk in Soybean Exports

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ABSTRACT

Commodity trading at both domestic and international levels involves many sources of supply chain risk and uncertainty. Risk management techniques are utilized by industry participants; however, there are unknown risks that can arise throughout the supply chain making effective risk management a difficult task. This study aims to address supply chain risk in soybean exports. A framework is created for a competitive bidding environment in which firms participate in an international import tender. Monte Carlo simulation is used to represent stochastic variables and derive an optimal bid under various scenarios. Sensitivity analysis is then conducted to measure the impact of key input variables on the output values. An alternative specification for risk management is also implemented into the framework. This study provides insight into supply chain uncertainty and incorporates that into a competitive bidding framework for optimal bid derivation and effective risk management.

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DEDICATION

This thesis is dedicated to Bruce Dahl. A mentor, colleague, and friend who had a tremendous impact on my success at NDSU.

He will be greatly missed.

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CHAPTER 1. INTRODUCTION

1.1. Overview

International grain trade has been and continues to be important to the United States' (US) agricultural industry. An abundance of crops produced domestically combined with strong foreign demand creates at environment prime for global trade activity from the United States. A recent World Markets and Trade report released by the United States Department of Agriculture (USDA) predicts United States corn exports to tie a record set just a year ago. Wheat exports are down slightly but continue to grow over time. Although a trade war has recently ensued with China, the world's largest importer of soybeans, international soybean trade remains of top priority in the agricultural industry and is now getting even more attention than ever before.

Effective supply chain management in agriculture is a crucial component to the success of all parties involved in the supply chain. This starts with the flow of commodities at the farmer level and moves throughout various avenues of the supply chain to end with the consumer. Effectively managing commodities at each step of the supply chain creates a more efficient flow and trading process between firms.

Agricultural supply chains contain both known and unknown variables. Unknown variables within a supply chain expose participants to supply chain risk. This uncertainty can come in the form of unknown costs that are introduced with commodity procurement, logistics, and commodity sales. The impact of supply chain uncertainty is realized in inter-firm competition. Firms competing in a commodity trading environment can strategically place themselves in various ways in order to gain a competitive advantage over their rivals. Some examples of risk mitigation techniques used by firms include commodity price hedging, transportation cost coverage, and anticipatory demurrage cost coverage.

The supply chain uncertainty in inter-firm competition is ultimately manifested in a competitive bidding environment. One way in which international trade transactions occur is through agricultural import tenders. Competition in the form of bidding plays an important role in the agricultural marketing industry and has two main functions: pricing and allocation (Wilson and Diersen, 1999). There is price discovery through the process of competitive bidding and adequate allocation occurs among suppliers. The firm/country seeking the commodity is in obvious need of it which creates a competitive trade opportunity for firms/countries looking to supply the commodity. Buyers also utilize auctions to promote competition among rivals and identify the low-cost supplier (Wilson and Dahl 2001). The competitive bidding process is one of if not the most efficient and effective way for a buyer to identify low-cost suppliers and create an environment of intense competition that allows the buyer to procure the commodity at the lowest possible cost.

This procurement process acts as a reverse auction where a foreign country is seeking to import a large volume of a certain commodity and entertains bids from potential suppliers in order to procure the commodity. Some international tenders are more privatized than others, and some happen more frequently and consistently than others as well. The popularity of this type of procurement competition is likely due to the volume and value of the commodity looking to be procured, where even small occurrences of price volatility can have an extreme impact on total cost (Wilson and Diersen 1999).

1.2. Problem Statement

From the perspective of the bidder, there are many forms of uncertainty that are introduced when seeking to submit a bid in the competitive bidding process. First, the prospective bidder may not be certain of his/her own cost structure. There may be price risk in procurement of the commodity itself. The bidder would also have to assume risk in the transportation process throughout the supply chain which may have unknown variables. There is price volatility in the transportation process whether it be truck, barge, rail or vessel. There is also the potential for bottlenecks to occur within a supply chain which then exposes market participants to potential demurrage penalties.

Second, there is also risk introduced from rival bidders. Because a majority of agricultural import tenders are sealed-bid auctions and remain fairly privatized, it is hard to gain information on the number of competitors and potential competitor bidding behavior. This creates uncertainty and potential risks that will have an impact on the optimal bid for any prospective bidder looking to participate in a tender.

Lastly, a prospective bidder may have difficulty when deciding how to derive an optimal bid for the tender. It is difficult to encapsulate all costs and potential uncertainty within a supply chain, especially an international supply chain with more than one form of transportation and many working components. The combination of all moving parts with underlying supply chain and competitor risks makes optimal bid derivation a difficult task.

1.3. Objectives

There are 4 main objectives of this study which aim to address the problems and uncertainty that firms face when looking to participate in international import tenders. The objectives are:

1. Accurately depict and measure the supply chain costs and uncertainty in which a potential bidder may experience when participating in an international soybean import tender.

2. Build a framework to accurately derive an optimal bid for a prospective bidder seeking participation in an international soybean import tender.
3. Conduct sensitivity analysis to determine and measure the impact of key input variables on expected profit, the probability of wining, and the optimal bid.
4. Introduce a risk measurement tool that can be used to measure and manage potential uncertainty when participating in the competitive bidding process.

These objectives aim to help firms looking to participate in the competitive bidding process identify and measure the potential risks, costs, and supply chain uncertainty and derive an optimal bid based on that. The amount of uncertainty due to the lack of information, complex supply chain, and dynamic bidding environment, makes optimal bid derivation a complex process. In addition to that, the volume and value of the commodity in the competitive bidding process is extremely high relative to other grain trading transactions which makes this decision-making process all the more important. An accurate supply chain depiction, cost valuation, and measurement of own and competitor uncertainty allows for precise optimal bid derivation and a higher chance of success in competitive bidding.

1.4. Procedures

First, a soybean supply chain is accurately developed from North Dakota (ND) to Asia. Historical costs are gathered for each component of the supply chain along with costs for other potential uncertainties. A profit-maximization model is created to derive the optimal bid for a prospective bidder seeking participation in an international soybean import tender.

The main profit function follows that of the seminal work of Lawrence Friedman. The function is as follows:

$$E(x) = (X - C) \cdot P(x)$$

E(x) is the expected profit returned for the firm. That is the value to be maximized. X is the optimal bid level at which the maximum expected profit is reached. C is the expected cost for the firm if they were to win the tender and supply the commodity. P(x) is the probability of winning the tender. This calculation is explained later in the study.

The model is setup as a stochastic simulation-based model and is solved using Monte Carlo simulation. The program used for the model is @Risk, which is a Microsoft Excel add-in program. Monte Carlo Simulation is a technique used to measure the probability of outcomes that are otherwise difficult to predict due to stochastic variables. Simulations are set up in @Risk based on various model parameters and the program runs each simulation 10,000 times to generate an outcome or probability.

An optimal bid is derived for a base case scenario and sensitivity analysis is then conducted. The sensitivity analysis is chosen for strategic variables that influence the optimal bid and overall expected profit. Lastly, an alternative specification for risk measurement is included as an additional tool which can be used for managerial and decision-making purposes within a firm.

1.5. Organization

Chapter 2 provides an explanation of the importance of supply chain management in agriculture and commodity trading. The chapter also depicts a soybean supply chain from North Dakota to the Pacific Northwest (PNW) and to a foreign destination (Asia). Supply chain costs are explained at each step of the supply chain. Potential risks in the supply chain are introduced in this chapter and risk mitigation techniques are also described. Lastly, previous studies pertaining to supply chain management and supply chain costs are highlighted.

Chapter 3 explains the competitive bidding process, types of auctions and winning variation environments. The chapter also highlights a formal program used in Egypt for international import tenders. Lastly, chapter 3 introduces previous literature about competitive bidding and specifies different modeling techniques used to represent the competitive bidding process.

Chapter 4 introduces and explains the empirical model. The base case scenario is developed and explained in detail. The data used in the model along with its sources are also explained. Probability distribution functions, correlations between costs components and their significance are all explained in this chapter. Lastly, this chapter provides a scope and breakdown of the sensitivity analysis included in the study.

Chapter 5 explains in detail the results of the base case along with all sensitivity analysis performed. This chapter aims to provide the impact that each sensitivity has on the optimal bid, probability of winning the tender, and expected firm profits. An explanation of why certain sensitivity analysis is done and the motivation for it is also explained in the chapter. Lastly, results are explained along with the impact of the alternative specification included in the model. Chapter 6 provides a summary of the study, highlights key results including that of the sensitivity analysis, and presents implications, limitations, and suggestions for further research.

CHAPTER 2. SUPPLY CHAIN MANAGEMENT IN AGRICULTURE

2.1. Introduction

This chapter focuses on supply chain management, its purpose and its application to agriculture. A soybean supply chain from ND to Asia is depicted and each element of that supply chain is explained in detail. Supply chain elements include costs and risks at each stage. The costs and uncertainty arise from both commodity procurement and logistics. Risk mitigation strategies are also described when analyzing each cost and its associated uncertainty. The flow of agricultural commodities throughout the supply chain is portrayed along with studies relating to supply chain management and its application to agriculture.

Supply chain disruption risk is also analyzed, described and related to the agricultural industry in chapter 2. Various studies relating to supply chain disruption are explained. These include studies using many different modeling techniques to measure the cost of congestion. Industry examples of supply chain bottlenecks, congestion and demurrage penalties are also described in the chapter in order to build a picture of the effects that disruptions can have throughout the entire supply chain.

2.2. Supply Chain Management

Supply chain management is the practice of actively managing supply chain processes at each step of the supply chain in the most efficient manner possible. More specifically, in the agri-supply chain it might be the practice of managing grain from the field to a local elevator to a processer or even to the end consumer. Efficient timing is an important variable in the agri-supply chain. For example, a soybean crush plant in China may purchase soybeans from a firm in the United States. This crush plant must rely on the industry participants in the United States to get the grain to the export facility in a timely manner. The crush plant must then have a vessel ready to load the beans and bring them back to China in order to be processed into the final product. If the beans are late getting to the export facility, demurrage charges will be incurred, and the crush plant must devise an alternative plan due to the delay in receiving the product. This is a basic example but builds a picture to represent the importance of timing and convergence of many moving parts within the agri-supply chain.

Transportation and commodity inventory are two critical components of supply chain management that also happen to be the most cost-absorbing (Ballou 1991). At the farm level, storage is an important asset that most farmers utilize. Harvest brings a large influx of grain at one time and that is often reflected by a decrease in cash market prices. It often makes sense for famers to store a portion of their grain with the anticipation that prices will increase in the coming months and the farmer will be able to retain a larger profit from storing and selling the grain in the post-harvest season.

Application of supply chain models in agriculture becomes beneficial when studying uncertainties within the supply chain. A study done by Borodin et al. (2016) analyzed the previous work handling agricultural supply chain uncertainty. The agricultural industry itself is under increasing pressure to become as sustainable as possible and also to provide food, energy and industrial resources to satisfy the demand of a rising world population (Borodin et al. 2016). More specific to this study, the intense competition within the agribusiness industry forces each competing firm to become as efficient as possible in order to gain a competitive edge. One way in which firms increase efficiency is in the area of supply chain management.

All different types of businesses in the agricultural industry are forced to make decisions under uncertainty. This is one of the main issues in the industry that poses all participants with risks. In upstream operations, agricultural producers are exposed to uncertainties in weather, production, prices, capital availability, etc. Further downstream, firms are exposed to uncertainties in market price volatility, supply chain timing, supply chain disruptions, etc (Borodin et al. 2016).

2.3. Supply Chain Depiction & Explanation

Agricultural products flow through many steps of the supply chain before reaching the consumer. Figure 2.1 shows a depiction of a soybean supply chain starting at the producer level and ending with the consumer. Appropriate deviations are added at each phase of the supply chain in which the commodities intended use may alter the path. The supply chain elements in blue are the elements specific to this study.

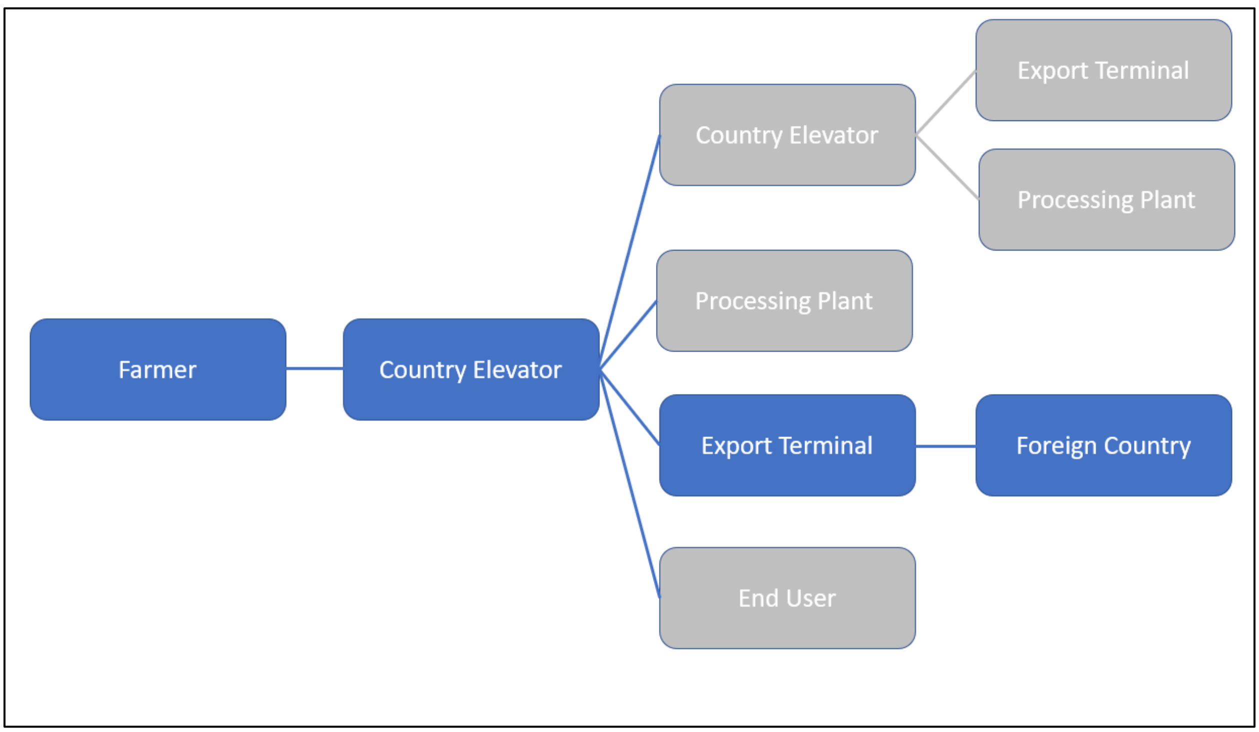


Figure 2.1. Supply Chain Depiction

Figure 2.2 is another supply chain representation built by CHS in an article titled, “Anatomy of a Grain Trade”. Although the specific commodity in this supply chain is not synonymous with that in this study, the supply chain flow is identical. It is important to note the modes of transportation that are used between each step in the supply chain. This includes primarily rail and vessel transportation. In the article, CHS grain traders comment on the importance of building a global supply chain network. Within that network, they mention the importance of relationship building along with risk exposure in the global supply chain. More specifically, the article addresses supply chain bottlenecks and the demurrage costs associated with that.

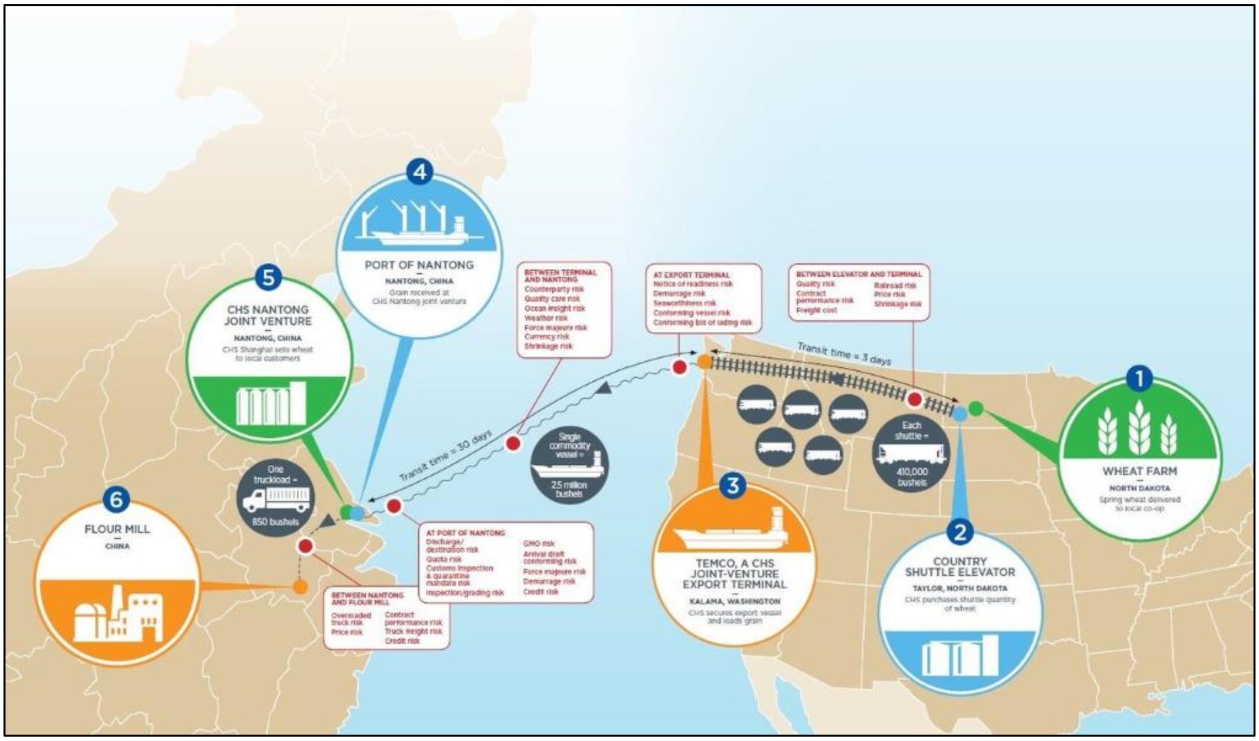


Figure 2.2. Anatomy of A Grain Trade (chsinc.com)

Each step of the supply chain is important to the commodity flow and plays a unique role in moving grain throughout the supply chain. First, the commodity is grown at the farmer level. Once harvested, it is usually delivered to a country elevator or shuttle elevator. A country elevator is a grain facility located in a rural area. They primarily purchase grain from farmers and resell it to other market participants at a higher price in hopes to gain a profit. A shuttle elevator is the same as a country elevator except they have access to rail for delivery of grain. Most country elevators use trucks to transport their grain to other sources of transportation such as a railroad or barge. Next, the grain is transported by rail or barge to either a processing plant or an export terminal. A processing plant is a facility designed to transform the commodity into an end good that can be utilized by the consumer. An export terminal is a facility located near a port that stores and exports grain to foreign destinations. After being exported, the grain is then shipped overseas to a processing plant where it is transformed into a final product for consumers. After being processed, a majority of commodities are then sent to a distributor/retailer. The job of the distributer/retailer is to sell the final good to the consumer.

Not all grain follows the exact same path through the supply chain. There are many factors that play unique roles in determining how grain moves throughout the supply chain. Type of commodity, distance from elevators/processing plants, demand, and price are just a few of these factors. For example, a farmer growing soybeans may be located near a crush plant. It may be more convenient or more profitable for the farmer to sell directly to the crush plant rather than to a country elevator. Another example would be a livestock owner purchasing grain for feed directly from a farmer (Landman 2017).

Throughout each step of the agri-supply chain, industry players are constantly competing in an environment that is ever-changing and extremely complex. Grain must be shipped from areas in which it is produced in abundance, to areas with high demand. Grain industry participants must overcome obstacles such as changing market prices, changing prices in logistics and logistical timing in order to move that grain to end markets. Industry participants are dependent on each other to successfully move grain throughout the supply chain. For example, grain buyers depend on the transportation industry to assist in delivering their commodities to end-markets in a timely manner (Carlson 1999).

Country elevators primarily consist of farmer cooperatives (co-ops), private owners, or grain companies. They are located mainly in surplus farming regions where grain can easily be consolidated into one location. They are often located along a rail line or river for means of accessibility to various modes of transportation. The primary goal of an elevator is to purchase grain from farmers and redistribute it accordingly.

After country elevators purchase the grain, the managers are faced with many decisions on what to do with it. The first decision is whether they should sell the grain immediately or store the grain in hopes to make a larger profit in the future. This decision is based on market conditions at that time along with strategic planning by the elevator managers. When carrying charges are positive, the market is giving elevators an incentive to store grain and sell it in the coming months. Positive carrying charge means the outward futures price is greater than that of the nearby. For example, if in the fall of the year the nearby soybean price is $10/bushel and the May soybean price for the next year is $12/bushel, then there would be an incentive to store the grain based on a few factors such as cost of storage, interest, etc. The opposite of that situation would be an inverted market. An example of an inverted market would be if in the fall of the year the nearby soybean price is $9/bushel and the May soybean price for the next year is $8/bushel, there wouldn’t technically be an incentive to store. However, dependent on market conditions and outlooks, managers may still decide to store the grain with the anticipations that prices will increase.

The next decision that must be made is to decide to whom the elevator managers should sell their grain. Typically, elevators will sell their grain to processors, merchandisers or brokers. Transportation is a critical variable when making this decision. A majority of the time, the elevator will be in charge of the logistics of the grain to the next destination.

A processor is a company that purchases a raw commodity and transforms it into another product. An example of a processor would be an ethanol plant that purchases corn in order to produce ethanol. Merchandisers are companies larger than that of a country elevator. They buy and sell grain just as a country elevator does, but at a much larger scale and to different markets. Merchandisers buy grain from producers, country elevators, brokers, and other merchandisers. They make up a majority of the participants that compete in the international competitive bidding process. The reason for this is because they have the ability to transport grain and therefore sell it to foreign markets. The competitive bidding process will be discussed in further detail in chapter 3.

2.4. Supply Chain Costs and Risks

A critical component of supply chain management deals with effectively measuring and managing the risks throughout the supply chain. Some risks are known and expected but others are unknown and often unexpected. This is a critical component of supply chain management, because without effective risk management an entire supply chain is susceptible to failure at all phases. Proper risk management is also vital for success within the agribusiness industry. One improper risk management policy can have long-term effects on a business' profitability along with their reputation. Supply chain risk management encompasses the aspects of effectively managing time, costs, information, among other variables that have potential risks associated with them.

According to a study done by Choi et al. (2016), there are 2 major types of risk within a supply chain system – operational risk and disruption risk. Operational risks are the uncertainties that firms face on a regular working basis. This may include uncertainties in supply, demand, market price, and cost. Even without disruptions in normal operations, these business components pose potential uncertainty. Proper operational risk control stems from understanding the sources of the risks and knowing the potential variability in them. Optimization models can be used to measure and control operational risks. On a farm level, operational risks may come in the form of supply uncertainty throughout the growing season, price uncertainty if not properly hedged, or crop input price uncertainty.

The supply chain depicted in this study starts with soybeans at a shuttle facility in Jamestown, ND and ends with the soybeans loaded on a vessel in the PNW to be shipped to a foreign destination. This is a complex, dynamic supply chain that deals with various modes of transportation and exemplifies the importance of timing. Costs components studied in this model include:

- Futures market
- Basis
- Shuttle elevator handling
- Rail tariff
- Primary rail market (COT)
- Secondary rail market
- Export facility handling
- Vessel demurrage
- Ocean freight

Not all listed costs are used in the same specific scenario. Determination of each cost component is dependent on the type of contract used and which party is responsible for each cost. The cost of the futures market is reflected in the futures price for the appropriate month. This cost can be mitigated by the act of hedging in the cash and futures markets. When a market participant is 100% hedged that means they have taken an equal and opposite position in the futures market compared to the position they have in the cash market. For example, if an elevator was long or owned 1,000,000 bushels of soybeans and wanted to be 100% hedged, they would short/sell 200 contracts of soybeans on the futures market. One futures contract is equivalent to 5,000 bushels which is where the 200 contracts is derived from. This eliminates potential price risk in the cash and futures markets. However, it does not eliminate exposure to basis risk.

Basis is a representation of the difference between cash price futures price. For example, if the local cash price for soybeans in Jamestown is $10.50/bushel and the nearby futures price is $11.20/bushel then the Jamestown basis would be $-0.70/bushel or commonly referred to as, "70 under". This value is a representation many different factors. The difference in these two prices is due to 4 main factors: transportation costs, storage costs, supply/demand conditions, and premiums/discounts. Transportation costs are dependent upon location of the local elevator and distance to the next destination. Storage costs are dependent upon time of year. The other two factors are dependent upon economic conditions at that time along with the condition of the commodity. Some examples of potential commodity discounts would be damage, test weight, foreign materials, etc.

If a market participant is 100% hedged in the cash and futures markets, they are still exposed to basis risk. One way in which this risk can be mitigated is through a basis contract. A basis contract locks in the basis value between the two parties in the contract which eliminates any fluctuation in the basis and therefore eliminates potential basis risk. The idea is to lock in the basis and price the contract at a later time in the future. This contract type may eliminate basis risk exposure; however, it exposes the participants to risk in the futures market.

Basis values also experience seasonality due to the factors listed previously. The origin basis in Jamestown, ND, is typically lowest during the harvest period. This is due to the rapid influx/increase in supply relative to demand conditions at that time. As the harvest period ends, basis values tend to increase and in the case of soybeans, tend to peak in the December-January time frame. This is a critical component to the decision-making process at both the farmer and country elevator level. Basis is used to evaluate timing and storage decisions by many participants in the agri-supply chain.

The cost of country handling is simply what the elevator charges to handle the grain. It is a representation of the handling margin for the elevator or also a representation of their profit margin. This data is hard to track but can be estimated through industry representatives. This is an important cost in the agri-supply chain that market participants should be sure to include in cost estimation.

There are 3 important costs involved in the process of moving grain by rail: tariff, primary market, and secondary market. A combination of the tariff rate and one of the other costs is the main mechanism for which rail shipment is priced. The tariff rate is the base amount that the shipper pays for use of the rail. It is set by the rail carrier and covers the cost of rail service, margin for the rail carrier, and potentially a fuel service charge (bnsf.com) Of those 3 inputs that make up the tariff rate, the fuel service charge is said to fluctuate with the price of fuel. The tariff rate may change monthly depending on the variables that make it up.

The tariff rate only covers the cost of trains to the destination. It does not secure the ability to reserve cars. That is done through either the primary or secondary rail market. The Certificate of Transportation (COT) program was established by BNSF (BN at the time) in 1988. This program had some key features that helped shippers mitigate risk including: forward contracting, auction allocation system, transferability, and guaranteeing placement (Wilson & Dahl 2005). Under the auction-based system, participants bid for Certificates of Transport (COT). Shippers places bid for cars in an auction setting that happens frequently. This system allocates cars with more economic efficiency because the allocation is based on who values them the most at the time rather than in the past where it was based on who applied first (Landman). The total shipping rate after the COT auction would then be the tariff rate plus the premium, which is the winning bid amount from the auction.

One major component of the COT program is transferability, which is what makes up the secondary market. The secondary market allows owners of COTs to sell the cars they don't need to buyers looking to purchase them. For example, if a grain elevator owns a COT and they decide that they do not need all the cars for that given month, they then have the ability to utilize the secondary rail market and sell the trip they don't need to another shipper looking to purchase it (Landman 2017). Just as the COT is priced, the secondary market price is priced as a premium or discount on the tariff rate. Due to intra-season supply and demand levels, there is variability in shipping demand. This mechanism provides means for shippers to purchase and sell cars based on that demand (Wilson & Dahl 2011 & 2005). By utilizing both the primary and secondary markets, shippers can mitigate risk. If only the primary market was available, shippers would be taking on a substantial more amount of risk because COTs are forward contracts for a fixed period.

2.5. Supply Chain Disruption Risk

The second type of risk within is a supply chain system is disruption risk. Supply chain disruptions are occurrences within a supply chain that have negative consequences on regular operations. These occurrences cause some degree of disorder within the supply chain which can cause minor or detrimental impacts to the entire supply chain (Vakharia and Yenipazarli 2008).

In relation to agricultural supply chains, disruptions are usually caused by unexpected weather events, increase in demand from the same and/or another industry, infrastructural issues among other occurrences, most being unexpected. These events caused at one point in the supply chain can create a bottleneck, which is a point of congestion within a supply chain. Bottlenecks, if severe enough can have detrimental impacts to the whole supply chain network. Some supply chain disruptions are minor and aren't realized throughout the entire supply chain; however, other disruptions can cause congestion/delays that become extremely impactful to the entire supply chain and the firm(s) operating in it.

Most agricultural supply chains, whether they be domestic or international have chokepoints along them. Chokepoints are crucial points on transport routes through which exceptional volumes of trade pass. They can either occur naturally or from manmade infrastructure. Most chokepoints fall under one of the following: seaports, maritime straits, road and rail networks, or inland waterways. Examples of inland chokepoints in the US are locks and dams along the Mississippi River. The US also has coastal chokepoints such as seaports located at the PNW and the Gulf of Mexico.

According to a global study done by Bailey and Wellesley (2017), the United States' inland waterway system is aging, and infrastructural investment will be needed within the near future or else congestion issues will arise. According to the study, "Upper Mississippi River and Illinois Waterway system is projected to reach 90% of its annual throughput capacity by 2020, leading to delays and a significant proportion of traffic shifting to other transport modes". The study also stated that the rail network is due to be constrained within the coming years. They forecasted that 30% of US railway corridors are expected to be above capacity, and a further 25% near or at full capacity by 2035. Any type of unexpected disruption to the United States supply chain network could have extreme impacts on inland and/or coastal chokepoints.

One way in which congestion can arise within a supply chain is from an increase in competition from another industry, particularly competition in transportation. An example of this is the recent Baaken oil boom in North Dakota and how that affected the shipping of agricultural commodities. Oil companies, during this time were able to consume a majority of railroad business due to having more price attractive and stable offerings. According to an article written by Williamson (2014) in combination with CoBank, "Rail service deteriorated dramatically beginning in late summer/early fall of 2013. Railroad terminal dwell times increased more than 20 percent due to greater demand, shortages of locomotives and lack of crews."

Weather disruptions during the winter months of 2013/14 also added to rail congestion. The bitter cold temperatures along with winter storms in the Midwest caused a decrease in train speeds along with many delays. A combination of weather disruptions, increase in shipping demand along with record harvests in the Upper Midwestern states, made it extremely difficult for agribusiness firms to move grain out of the Upper Midwest to the PNW.

The disruption attributed to the oil boom eventually backed up and/or diverted enough service that is was noticed throughout the country. "The huge hub of railroads was so congested that railroads began diverting trains to St. Louis and Memphis without shipper input. When these terminals exceeded capacity, terminals like Kansas City and Tulsa also became congested to the point that BNSF began to ask short-lines and terminal railroads to hold trains until room could be made to move them" (Williamson 2014).

An eventual decline in the price of oil slowed the demand from the Baaken formation, which mitigated the congestion issue. Although this isn't a current problem in the industry, merchandisers understand this is a looming issue which could easily arise again in the near future.

Brazil is a country that is currently experiencing a major increase in soybean production. The increase in production is stemmed from a major increase in foreign demand. Although Brazil has the available land and appropriate weather conditions to sustain a production increase, the country's transportation infrastructure has not been able to keep pace. According an article by King (2017), "Due to the poor inland logistics and heavy reliability on trucks, our inland logistics are less efficient and far more expensive than those of our main competitors – the U.S. and Argentina". The current infrastructure is being utilized at maximum capacity, which means that any type of exogenous delay is critical. In early 2017, heavy rains struck a portion of the country and drivers in that area were reporting that it was taking 14 days to cover the 620-mile route (King 2017). Because of the congestion, routes were diverted, and transportation costs increased significantly.

Seasonal delays during peak grain exporting times are common in the country. Historically, delays in the Port of Paranagua have reached 45 to 60 days (King 2017). Delays like this significantly increase transportation costs and make Brazil a much less attractive global supplier.

A substantial investment towards transport infrastructure must be made by Brazil if the country wants to realize its full export potential (King 2017). Progress has been made and the country is continuing to overcome the logistical problems it has been facing. According to King

(2017), “Delays at key ports such as Santos and Paranagua at the turn of the year were far lower than in previous years. Moreover, Brazil’s ports have been boosting capacity.”

Brazil isn’t the only country experiencing domestic congestion. Although it may not be as severe, The United States is currently facing transport issues that have caused supply chain disruptions and will continue to do so into the future. Of the $40 billion in annual grain and soybean exports from the US, about 60 percent is transported by barges on rivers (Polansek and Plume 2017). One river in which a recent bottleneck arose is the Ohio River. In the early fall of 2017, a shutdown caused by worn or missing sections of a dam, backed up river traffic and created a line 50 miles long of traffic waiting to get through Locks & Dam No. 52. Due to the aging infrastructure, the lock has become a major chokepoint along the river.

Delays such as this not only had an adverse effect on transportation timing but were also reflected in prices. Grain prices were bumped at export terminals which benefited international competitors such as Brazil (Polansek and Plume 2017). The price movements were realized all the way down to the producer level. Because of the delays, many grain handling facilities had no other choice but to lower prices and stockpile grain. With margins already extremely tight, an unexpected loss due to disruptions in the supply chain is a critical hit to producers and grain handlers. Shipping companies were also hurt by the disruptions. “Barge operator Campbell Transportation Company of Pittsburgh estimated a loss of $1 million in revenue in September and October because of the delays” (Polansek and Plume 2017).

Because a majority of the country’s locks have exceeded their half century design lives, nearly half of the vessels using the nation’s inland waterways are now experiencing delays according to the American Society of Civil Engineers. Delay time per lock has nearly doubled on waterways since 2000, rising from 64 minutes in 2000 to 121 minutes in 2014 (Polansek and Plume 2017).

According to Polansek and Plume (2017), "An October National Waterways Foundation study said a major lock failure in the Midwest could cost shippers $1.5 billion per year in added costs and overwhelm existing rail and road capacity." These inland delays and added costs are becoming crucial for the United States. As soybean production continues to grow in competing countries such as Brazil, the United States can't afford to experience added delays and costs if the country wants to keep a competitive edge in soybean exports among other commodities.

Another one of the United States' major export locations, the PNW, experienced critical supply chain disruptions in the spring of 2017. A majority of the grain that isn't exported from through the Gulf of Mexico is sent through the PNW. Severe weather in the spring of 2017 along transportation routes to the PNW caused significant delays which had adverse effects on market participants trying to export grain.

Extensive rainfall caused washouts and landslides which prevented shuttle trains from reaching the PNW in normal time. Blizzards along transportation routes to the PNW also caused major delays. The heavy rainfall at the port locations stopped the loading of vessels, which created another source of congestion at the port. One report indicated that in February, there were about 60 ships in port or waiting offshore. The monthly loading capacity in that area in the PNW is only 40 ships. This was expected to cause delays of up to 20 days (*Thomson Reuters* 2017).

Due to the disruptions, the cost of freight increased quickly. Reported in February 2017 by Thomson Reuters, "The average rate in the secondary market for spot BNSF shuttle railcars has hit $2,000 above tariff rate per car, up from $1,267 above tariff a month ago. A year ago, it was $108 below tariff, according to the U.S. Department of Agriculture data".

The major delay times at the PNW caused many foreign customers to choose alternative routes, such as the Gulf Coast terminals to transport the grain they were purchasing. Even though shipping times from the Gulf can be up to two weeks longer, many Asian customers felt it was beneficial to utilize that route instead of paying the demurrage penalties, waiting, and shipping through the PNW. Many Asian buyers scrambled for fill-in supplies from China while Japan tapped its emergency grain stockpile (*Thomson Reuters* 2017).

China, one of the major soybean importers also experienced significant congestion issues in the fall of 2017. Shipping data from Thomson Reuters Eikon showed 17 dry-bulk carriers, most holding soybeans, anchored off Rizhao port waiting due to congestion. Port congestion along with negative crushing margins caused China to resell more than 500,000 tonnes of soybeans (*Thomson Reuters* 2017).

2.6. Supply Chain Congestion Modeling Techniques

A powerful modeling technique for measuring and managing congestion is the use of queuing theory. A queuing system is one in which customers receive some kind of service from a server and if that service is not available, they wait for it. This then forms a waiting line which is better known as a queue. Queuing models can then be developed for particular industries and supply chains. Customer waiting time, queue length, and server idle time are among a few of the evaluation criteria developed from the use of queuing models (Aziziankohan et al. 2017).

Leachman and Jula (2011) performed a study on congestion analysis regarding containerized imports to the United States from Asia. They developed a queuing model to estimate container flow times through port terminals. The estimation of container flow times through ports was derived as a function of volume, infrastructure, staffing levels and operating schedules. The model developed was able to be industry applicable and also easily integrated with other queuing models that incorporated various parts of the supply chain. Many other studies have proven that queuing models are an effective tool for congestion measurement and mitigation (Aziziankohan et al. 2017, van Woensel and Cruz 2009, Heidemann 1994, van Woensel and Vandaele 2006, Garrido and Allendes 2002).

Although queuing theory is a powerful tool for congestion modeling, there are many other techniques that have been used to model congestion. Jones, et al. (1995) created a spatial price equilibrium model to study wheat export shipments through the PNW. They created hypothetical supply chain disruptions and analyzed the changes in commodity flows. Bai, et al. (2011) used linear programming and produced a heuristic algorithm to show the effects of congestion on biofuel refinery location design and total system costs.

Jones, et al. (2011) developed a System for Import/Export Routing and Recovery Analysis to predict flows between foreign countries and North American ports. Fan, Wilson, and Dahl (2015) developed a stochastic network-flow model to analyze risk potential of container imports into the United States.

Given the supply chain used in this study, disruptions and congestion are most likely to occur along the rail line or at the port. Previous industry examples have exemplified the possibilities of these disruptions occurring and the effects it has on the entire supply chain.

2.7. Summary

This chapter provides an overview of supply chain management in agriculture along with its importance and potential risk for participating firms. A supply chain relative to this study is depicted along with another supply chain compiled by CHS to represent the flow of commodities throughout an international supply chain. Supply chain variables are depicted and described at each stage. The associated risk of each supply chain cost is also mentioned. Certain costs allow for risk mitigation by hedging, choosing various contracting types, along with logistical price coverage. Other supply chain risks are more difficult to account for, including demurrage. Supply chain disruption risk and its importance in supply chain management is examined in this chapter. Lastly, various industry examples of supply chain congestion and demurrage penalties are highlighted to show the impact of disruption risk in a real-life setting.

CHAPTER 3. COMPETITIVE BIDDING: BACKGROUND AND PRIOR STUDIES

3.1. Introduction

The competitive bidding process is used actively in the agribusiness industry as a form of conducting business. More specifically, it is used in the form of international tenders where governments, private firms or other institutions will invite bids from competitors all across the globe in order to supply a certain volume of a requested commodity to them. Potential suppliers will submit bids based on their cost structure among other variables in hopes to win the tender. The winner of the tender will then supply the buyer with the commodity.

This chapter examines the seminal studies of competitive bidding along with other relevant literature to the topic. The competitive bidding process is explained in detail. An application of competitive bidding to agriculture is introduced by analyzing an industry example. Lastly, auction types are differentiated along with winning bid selection variations.

3.2. Competitive Bidding Modeling Techniques

There are 3 main model types that seem to be prominent in competitive bidding research. They are simulation-based models, deterministic models, and game theory decision-based models. The model used in this study is a simulation-based model using Monte Carlo simulation to derive optimal bids.

Deterministic models are based on mathematical equations to represent relationships among variables and don’t include any randomness at all. This means that for a given set of input values, deterministic models will always generate the exact same output. Simulation-based models are used to predict outcomes when there is randomness and unknown variables in the model. This modeling technique is designed to account for risk and uncertainty in model building process. Rather than just replacing an unknown variable with an average number, Monte Carlo Simulation replaces unknown variables with probability distributions. This accounts for randomness and potential risks in the model. After probability distributions are created to fit the data, the model is then simulated over and over using different values from the distributions to derive results. The number of iterations or times the model is ran depends on how complex the model is and how much uncertainty is included in the model. A distribution of potential outcomes is generated to obtain final results. The Monte Carlo Simulation technique allows users to fit the data to many different types of probability distributions. Instead of just assuming a normal or "bell curve" distribution, data can be fit to other types of distributions which may represent it better.

Simulation-based models not only generate outcomes, but also determine how probable those outcomes are. Monte Carlo Simulation also allows users to perform sensitivity analysis on the results. When using deterministic models, it is hard to know which input variables impact the output the most. Monte Carlo Simulation is able to represent how much each input variable impacts the output value(s).

More specific to competitive bidding, game theory decision-making models are often utilized. Game theory models organize a competitive bidding environment as a game with various objectives, inputs, and outputs. Depending on the objective of the study, many different techniques and strategies are used for decision-making. These types of studies take a slightly different approach to model building compared to most deterministic and simulation-based models.

3.3. Prior Studies

Lawrence Friedman (1956) paved the way with the first major study regarding competitive bidding. Other studies such as Gates (1967), and Carr (1982) based their ideas from

Friedman and made valuable contributions to the literature. This study will follow a baseline idea of Friedman's model with appropriate deviations to reach the objectives.

The objective of Friedman's study was for a potential bidder to maximize profit by submitting a bid at an optimal level. He analyzed previous bidding behavior of competitors to derive a bid function for each competitor and predict future bidding behavior from that function. In order to derive an optimal bid for a competitor, Friedman used a profit function multiplied by what he termed as the 'probability of winning' [p(x)]. The function is as follows:

$$E(x) = (X - C) \cdot P(x)$$

Where E(x) is the expected profit, P(x) is the probability of underbidding all competitors and winning the auction, X is the bid amount submitted, and C is the estimated cost. The probability of wining was derived through a ratio of previous bidding behavior to own cost for each competitor. This creates an underlying distribution for each competitor in which a probability of winning can be drawn from. The product of the individual probabilities for each competitor would result in the probability of winning the tender. As expected, results indicated that a higher bid would result in greater profit but would also decrease p(w); whereas, a lower bid wouldn't be as profitable but would have a higher p(w). One advantage of using Friedman's model is that it is relatively simple and easy to comprehend. Industry participants are able to easily utilize his model for bid prediction if they have the required previous bidding data.

Gates (1967), used an approach similar to that of Friedman, except the representation of the probability of winning was done differently in his model. Gates uses the same bid/cost ratio as Friedman to derive the probability of winning against a potential competitor; however, the studies differ when these probabilities are combined to represent the probability of winning the entire tender against multiple competitors (Crowley 2000). Instead of simply multiplying the individual probabilities to obtain the probability of winning the tender, Gates suggests this formula is the appropriate way to determine the probability of winning:

$$P_{\text{winning}} = 1/[1-P_A)/P_A + (1-P_B)/P_B + (1-P_C)/P_C + \dots + (1-P_N)/P_N + 1]$$

Where a trial bid is used and the probabilities of competitor A, B, C, … , N placing a bid higher than the trial bid is given by $P_{A,}$ $P_{B,}$ $P_{C, \dots,}$ $P_{N,}$ respectively (Crowley 2000). In this scenario, Friedman's model would suggest,

$$P_{\text{winning}} = P_A \text{ X } P_B \text{ X } P_C \text{ X } \dots \text{X } P_N.$$

It is evident that Friedman's model takes into consideration the area of the distribution where competitors are placing a bid higher than that of the trial bid; whereas, Gates considers the opposite. As a result, Gates' model tends to choose optimal bids higher than that of Friedman's model when they are compared in an identical situation. It can be concluded that Gates' model would generate a higher profit but have less of a probability of winning the tender and the opposite can be said about Friedman's model (Hosny and Elhakeem 2012). One disadvantage of Friedman's model is that it suggests the variability of competitor bids to be based strictly from historical data, instead of focusing on a present reality for the cost estimate (Crowley 2000).

This difference set the stage for an abundance of research done on the comparison of the two models (Benjamin 1972, Curtis and Maines 1973, Griffis 1992, Skitmore et al. 2007). Many authors have taken various comparison approaches to compare the two models and conclude which of the two they prefer. Research on this controversy is still being done today.

With the seminal work of Friedman and Gates, Carr (1982), was able to produce a more articulate model that focuses on cost estimation and the markup value error associated with that. Carr's model is not restricted by the same assumptions in which Friedman's and Gates' are. His objective was to produce a general bidding model that can be applied to any competition in which a bidder's cost distribution and potential opponents' bid distributions can be estimated (Carr 1982).

When Friedman estimated his model, he only took into consideration the estimated cost which makes sense because true cost is unknown at the time of bid placement. However, Friedman failed to address the fact that the optimal bid price is directly affected by the inaccuracies in cost estimation (Takano, Ishii, Muraki 2014). This is crucial because an inaccurate cost estimation could end up in extreme loss for a tender participant.

Carr concludes that Friedman's model is beneficial and accurate when costs are constant, and bids only vary in markup value. However, he argues that this is not the case in most situations, and relative costs are random variables and have direct impact on the markup value associated with the bid.

As Friedman, Gates and Carr conclude, participants in the competitive bidding process are faced with many uncertainties. They are uncertain of their own costs, competitor costs, number of potential competitors, among other firm specific uncertainties. All of these uncertainties pose substantial risk to potential bidders and they must include these risks when determining their optimal bid. Many other studies have been performed aiming to evaluate bidder uncertainty (Naert and Weverbergh 1978, King and Mercer 1990, Capen et al. 1971, Carr 1983, Chapman, Ward and Bennell 2000, Skitmore 2002, Skitmore 2004, Hosny and Elhakeem 2012.)

A recent study done by Ribeiro et. al (2017) uses a real options approach to maximize the optimal bid. It is assumed that each bidder has the flexibility of whether or not to accept the contract if they win the tender. Due to that assumption, the model also accommodates for the inclusion of penalty costs if a tender winner refuses to enter into the contract. The model is based on the valuation of a specific real option that can only be exercised by the winner of the tender. Two different components are integrated into the maximization problem:

1. The value of the option to sign the contract
2. The probability of wining the bid

The authors concluded that maximizing the value of the option of whether or not to sign the contract, weighted by the probability of winning was an effective approach to determining the optimal bid. They also concluded that the optimal price is higher when penalty costs are included in the model. This is because potential bidders/managers will need to present a higher bid to account for such a cost (Ribeiro et. al 2017). The model is also based on market and firm-specific information which also makes is an applicable tool for decision makers in the construction contracting industry. Although this study isn't applicable to the agribusiness industry, it is important to note that it is often valuable to create a model that can easily be applied and utilized by managers in a certain industry. This thesis aims to do just that.

Another way to approach the modeling of competitive bidding is by using a type of criteria evaluation method. Cagno, Caron and Perego (2001) used a simulation approach based on the Analytic Hierarchy Process. They were able to derive the probability of winning by evaluating competing bids on a multiple criteria basis. Lai, Liu and Wang (2002) performed a similar study in which they determined the preferred markup level for a bidder by evaluating specific criteria. Many other studies analyzing competitive bidding based on a type of criteria evaluation method have been performed (Dozzi, AbouRizk and Schroeder 1996, Watt, Kayis and Willey 2009, Shafahi and Haghani 2014).

Takano, Ishii and Muraki (2014), recently performed a study on competitive bidding by developing a stochastic dynamic programming model. The in-depth focus of their study was on the effects of inaccurate costs estimates on sequential competitive bidding. The interesting take-away from their study that will be used in this study is the value-at-risk (VaR) constraint. VaR is a financial risk measure that is used to quantify the level of financial risk within a firm, or potential tender bid in this case. This purpose of executing this constraint is to protect the firm from the possibility of realizing a large loss due to uncertainty in potential costs. In previous literature, most focus has been on profit maximization and very little work has been done on the focus of risk mitigation from inaccurate cost estimates (Takano, Ishii and Muraki 2014). The inclusion of the VaR measure will be explained in more detail in Chapter 4.

The study utilized numerical simulations between two different model setups in order to realize the impact of the VaR constraint. One model accounted for cost uncertainty and the other did not. They concluded that the VaR constraint was not significant in the model that accounted for cost uncertainty through expected profit. However, the VaR constraint proved to be significant for the model that did not account for cost uncertainty. Imposing the VaR constraint in the model that did not account for cost uncertainty increased profits to a similar level of the model that included uncertainty about the costs (Takano, Ishii and Muraki 2014). This proves that the VaR constrain was indeed significant.

3.4. Competitive Bidding in Agriculture

There has not been an abundance of research performed when combining agriculture and competitive bidding. Just because there have not been many relevant studies applying the tender process to agribusiness, doesn’t mean competitive bidding isn’t relevant in the world of agriculture. Tenders are common in the form of commodity procurement across the world. They are also common for procurement purposes in the livestock industry.

A study done by Crespi and Sexton (2004) analyzed the bidding behavior of beef-processing plants bidding for cattle in the Texas Panhandle. This study had the conceptual idea of modeling bidding behavior of competitors to form a derivation of an optimal bid scenario for a beef-processing plant in the procurement process. The auction type utilized for cattle procurement was the same as the one used in this study, first-price sealed-bid auctions. Bid functions for each processing plant were derived using regression. Free on Board (FOB) feedlot prices for spot market purchases were regressed on variables such as whole sale boxed-beef price, live cattle futures price, yield, distance, and others.

Simulations were then conducted in replication of the actual auctions held and results were compared to the real-life situations. It was concluded that in relation to the simulated auctions, cattle in the region studied sold for a lower price, were sometimes acquired by a plant that didn't have the highest willingness-to-pay and were consistently purchased by the same plant (Crespi and Sexton 2004). Factors such as inconsistent bidding, low number of bidders, and business loyalty were concluded to be a few of many reasons contributing to that. Although this study follows the same conceptual framework of replicating bidding behavior in a tender setting, it relies heavily on past bidding behavior and lacks focus on the cost structure of the firms participating in the tenders.

Wilson and Dahl (2001) studied competitive bidding in the case of minor oilseeds. This was an analytical study in which the authors formed bid functions for suppliers in the tenders based on previous bidding data. Bid functions were formed using regression. Previous bids were regressed on a cost indicator value relative to the commodity at hand. From that data, optimal bids were derived using a profit function along with derivation of the probability of winning the tender.

Results indicated that there is significance in optimal bid derivation and the number of bidders. An increase in the number of bidders, decreases the optimal bid. The frequency of random bidders also proved to have an impact on the optimal bid. Lastly, information available among rivals proved to be of significance in optimal bid derivation. These are 3 critical variables that have a direct impact on optimal bid derivation and should be taken into consideration when the appropriate data is available.

A similar study performed by Wilson and Diersen (1999) analyzed the bidding strategies for suppliers participating in international wheat import tenders. A stochastic simulation model was used to derive optimal bids and bidding strategies for competitors. This study also utilized simulations to perform sensitivity analysis on critical variables in relation to deriving the optimal bid. One variable in particular was cost differentials. It was concluded that firms with lower costs would have lower optimal bids and high-cost firms would have higher optimal bids. As the number of bidders increases, this becomes more advantageous for low-cost firms relative to high-cost firms because the optimal bid decreases.

Another important concept highlighted in this study was that of the winner's curse. This concept is used to describe outcomes of competitive bidding situations where the winner of the tender ends up with extremely low or even negative profits (Wilson and Dierson 2001). Each participant in the tender submits bids based on expected costs and some markup value over those costs. The winner of the tender may have won because their cost estimate was lower than that of their competitor's. Because these costs are unknown in their entirety, bidders may often underestimate true costs when deriving their bid. Intense bidding competition can create an environment in which profit margins are extremely tight to begin with and underestimation of true costs can result in negative profits for the winner. In that case, the winner's cost estimate is biased relative to true cost, and he/she is said to be "cursed" with negative profits (Thaler 1992).

The winner's curse was first studied by Capen, Capp, and Campbell (1971). These three petroleum engineers analyzed oil lease auctions and, more specifically, why the winners of these auctions were constantly suffering from extremely low or negative profits. They concluded that the auction winners were the bidders who overestimated the value of the land being auctioned for oil drilling rights, and, therefore, were "cursed" with extremely low or negative profits.

A book written by Thaler (1992), highlights studies of the winner's curse in many different auction environments including company acquisition, construction project tenders, book publishing, and free agent markets in baseball. This goes to show that the winner's curse is relevant in many different auction settings.

3.5. The Competitive Bidding Process

The competitive bidding process in the international grain trade industry is done in the form of a first-price sealed-bid tender. A majority of international import tenders are set up in terms of a country's government looking to purchase a certain amount of a certain commodity. The buyer submits a notice detailing the criteria of the tender such as commodity, amount to be bought, and a deadline for bid submission. After the notice has been issued, any firm in the world is able to submit one or more sealed bids. There may be certain stipulations on maximum bids that can be submitted, but that is unique to each tender. Each potential bidder/supplier is faced with many unknowns such as, which firms will be submitting bids, how many firms will be submitting bids, cost structure of competing firms, and even their own cost structure. This makes the process of deriving an accurate optimal bid extremely complex and faces the bidder with potential risks.

When the time allotted for bid submission has expired, the firm(s) with the lowest bids submitted will win the tender and then be required to supply the buyer with the commodity requested. There may be more than one firm chosen to supply the buyer with the commodity, depending on the amount of the commodity the buyer is looking to purchase. Often times, the two or three lowest bidders are chosen to supply the buyer with the commodity.

3.6. Industry Example

A major user of the international import tendering process is the General Authority for Supply Commodities (GASC) of Egypt. The GASC is an economic entity formed for the purpose of procuring commodities within the framework of a strategic plan. The entity also works to raise agricultural production efficiency, create competitiveness, strives for structural sustainability and balance in state and local markets, among other targets (www.gasc.gov.eg)

Egypt is the biggest importer of wheat in the world and a major procurement strategy for the country is utilizing the tendering process. The GASC issues frequent notices for tenders seeking wheat of various varieties and in various volumes. The economic entity has a set of requirements that competing firms must abide by when submitting bids and following through with the tendering process and supplying of the commodity. The requirement set was revised by the GASC in February of 2018.

Some of the changes in the requirements were in benefit of the importing country and others were to supplement the supplier in regards to demurrage fees. The GASC lowered the protein requirements for wheats such as Russian, Romanian, Ukrainian, French, U.S. soft, and U.S. hard red wheats. This was done in hopes to increase bidder competition and moderate price increases. If the protein requirement is lowered, more suppliers may be willing to participate in the tenders and the current participants may be able to supply wheat at a lower price which would create more competition and drive down the bidding price in benefit of Egypt, the importing country.

The GASC also made a change to the demurrage policy in response to supplier complaints and a decrease in tender participation. A change in the inspection process increased the vessel unloading time substantially, which in turn increased delays for unloading and the added costs were put on the supplier. In response, many suppliers quit participating in the tenders or increased their bid amount to account for potential demurrage, which faced suppliers with extreme exposure to risk and uncertainty. A tender was nearly halted in the spring of 2018 due to a standoff over demurrage payments which led suppliers to withhold their offers (af.reuters.com) In response to that, GASC set a cap on demurrage fees. They now only require the supplier to pay the first 12 days of demurrage at $12,000 per day. After that time, the supplier won't be responsible for the demurrage payment. Prior to this policy, the supplier was responsible for all demurrage fees no matter how long the delay. This made it extremely difficult for suppliers to determine their cost structure and also exposed them to substantial risk. The new fixed-rate system helps with cost calculation and also reduces risk exposure for the suppliers (af.reuters.com). Although these policy changes are unique to the GASC and their wheat importing process, they provide a good example of the process and guidelines that suppliers must follow when participating in international grain tenders.

3.7. Auction Types

There are 4 common types of auctions used everyday business: English auctions, Dutch auction, first-price sealed bid auctions, and second-price sealed-bid auctions. Other auction types are certainly utilized, but these 4 seem to be the most prevalently utilized in business transactions.

An English auction is an ascending auction where the auctioneer picks a starting price for the item being auctioned and increases that price until only one bidder remains. That bidder then wins the item. A Dutch auction is a descending auction where the auctioneer initially starts the bidding process at a very high price and decreases that price until a bidder stops the auction and claims the item at the current price offered by the auctioneer. A first-price sealed bid auction is a much more private type of auction in which bidders submit sealed bids and the highest bid wins the auction. A second-price sealed-bid auction is the same as a first-price sealed-bid auction, except the second highest price is paid by the winner. The bidder with the highest bid still wins the auction, except they pay the price equivalent to the second highest bid. This type of auction is also known as a Vickery auction. The reason it is done this way is because it give an incentive for participants to submit realistic, competitive bids. First-price sealed-bid and second-price sealed-bid auctions can be used in both a buy or sell setting.

In both the English and Dutch auctions, bidders are aware of how many competing bidders they have. However, in first-price sealed-bid and second-price sealed-bid auctions, bidders are often unaware of how many competitors they have. This is a critical component in bid derivation for those submitting bids.

This study focuses on the use of the first-price sealed-bid tender process. A tender is another way of referring to an auction setting, in which offers or bids are accepted for a contract, project, or task assigned by the initiator of the tender. The process of competitive bidding works in the way of a reverse auction, where firms submit bids and the lowest bid will win. The initiator of the tender is looking to procure a commodity, which means the bidders also act as suppliers to that firm.

3.8. Winning Bid Selection

Based on the different auction types, there are also different methods in which the winning bid is determined. The main methods include low bid, average bid, and next best bid. The low bid method is the most common. It is simply, the acceptance of the lowest bid in the competitive bidding process. This method is as close of an example as pure competition as possible. This method forces bidders/suppliers to continuously try and lower costs to remain as competitive as possible. These savings are then passed to the buyer/issuer of the tender through the competitive bidding process (Ionnau and Leu 1993).

The next best bid method is slightly different. In this case, the bidder who submits the lowest bid will still win the tender but will pay the price of the second lowest bid. It is important to remember that this is in the context of a reverse auction setting, so the opposite would occur in a normal auction setting. The next best bid method is utilized when a second-price sealed bid auction is performed.

Lastly, when an average bid method is exercised, the winner of the tender is the bidder who submits a bid closets to the average of all the bids submitted. The reason this method may be used is to avoid the possibility of issuing a contract to a bidder who submits an unrealistically low bid. When an unrealistically low bid is submitted, many problems can occur for both the bidder and the buyer. Such problems include excessive claims and disputes, schedule delays, reduction in project quality, increased costs, and others (Ionnau and Leu 1993).

A study done by Ioannou and Leu (1993) analyzed the difference between the low and average bid methods and the effects that these methods can have on bid submission in the competitive bidding process. They used applications of both an analytic and a Monte Carlo simulation model to perform their study. This study was done in application to the construction industry, so their implications reflect that. The authors concluded that a departure from the low bid method has the potential to improve longevity of construction firms and also improve the relationships between the owner and contractor. More obvious, the average bid method also has the ability to eliminate the accidental and deliberate unrealistically low bids (Ioannou and Leu 1993). Although the average bid method seems attractive, the main argument against it is that it does not promote price competition between competing firms. It is shown in the study that a cost savings breakthrough is not realized as much in the average bid method compared to the low bid method, unless the breakthrough is realized by all competitors.

There is not an abundance of supporting literature on the average bid vs. low bid method in relation to the agribusiness industry. That could be because the competitive bidding process isn't quite as popular and is slightly more private than competitive bidding in the construction industry. Most previous literature in relation to model building in competitive bidding is written for use of the low bid method. Also, the tender process in the agribusiness industry seems to use this method. For those reasons, the low big method will be used in this study.

3.9. Summary

This chapter focuses on competitive bidding by examining the seminal studies, development of literature and its relation to competitive bidding in agriculture. Friedman and Gates set the ground work for competitive bidding. Most literature builds off of the foundation of their work and adapts to various objectives. A study performed by Takano, Ishii, and Muraki (2014), includes a VaR analysis to measure risk exposure in competitive bidding. Most previous literature focuses primarily on profit maximization and ignores potential risks and uncertainty. Firms participating in competitive bidding are exposed to substantial risk and its measurement and management are crucial when participating in competitive bidding. Therefore, a VaR analysis is implemented in this study as an alternative specification to the model.

The competitive bidding process is explained in detail in this chapter. An industry example of the Egyptian wheat import tender process is also highlighted to show the process in a real-life situation. Lastly, various auction types are explored along with winning bid selection types.

CHAPTER 4. EMPIRICAL MODEL

4.1. Introduction

This model is specified to represent a competitive bidding scenario of an international import tender for soybeans. More specifically, it is built to derive an optimal bid for a prospective bidder considering participating in the tender. A base case scenario is developed for a prospective bidder. Sensitivity analysis on strategic variables are then performed to show the impact of important variables on the optimal bid. Lastly, an alternative specification is exemplified using VaR analysis.

The supply chain used in the model represents an origin of Jamestown, North Dakota and end destination of either an export facility in the PNW or the importing country. Soybeans have grown to be one of the biggest crops in North Dakota outpacing corn and wheat in terms of harvested acres. A majority of the beans grown in North Dakota are exported out of the state and even the country. The most prominent pipeline for export from North Dakota is by rail to the PNW and off to China, which is the biggest importing country of United States soybeans.

The final destination and risk parameters for the bidder will vary based on the incoterms of the tender. The incoterms of a contract are essentially a set of rules that determine the conditions for the buyer and seller. This would include at what point the buyer has responsibility of obligations, costs and risk and at what point the seller gains responsibility of obligations, costs and risk. They are published by the International Chamber of Commerce and are popularly used around the globe for business transactions. The 3 incoterms used in this model are:

1. Buy at origin & sell Free On Board (FOB) ship
2. Buy delivered & sell FOB ship
3. Buy at origin & sell Cost, Insurance and Freight (CIF) China

The first incoterm combination would mean that the bidder assumes responsibility of the soybeans at their origin (ND) and the selling/bidding price would be FOB ship. This would mean that the buyer of the soybeans would gain responsibility when the beans are loaded on the vessel for export.

The second combination is similar to the first except instead of the bidder buying the beans at the origin, they are buying them delivered to the port. This means that they don’t aren’t responsible for the transportation costs from ND to the PNW. Instead, they buy the beans already delivered and sell them FOB ship. Lastly, the third incoterm combination assumes obligations, costs, and risks on behalf of the bidder at all points of the supply chain. The prospective bidder purchases the beans at origin (ND) and the bidding/selling price includes the cost of ocean freight to the importing country. The importer would then gain responsibility when the vessel arrives to the importing country.

The incoterms of a contract become extremely important when demurrage occurs in the supply chain. Supply chain congestion can cause delays which eventually have a ripple effect throughout the entire supply chain and additional costs are often incurred because of it. For example, if there is congestion on the rail line from ND to the PNW, the exporting vessel may arrive before the soybeans do and then demurrage costs will be incurred. The decision of who pays those costs are included in the incoterms of the contract. An example of this is presented in chapter 5.

This chapter explains the empirical model in detail. Setup of the model is described along with implementation of any additional analysis to that of the base case. The additional implementations include a cost measurement of demurrage and an alternative specification of

VaR analysis. Lastly, the data used for the model is described in detail including the distributions created to represent each cost along with the correlations of costs.

4.2. Base Case

A base case scenario is set up to represent the most typical situation in the competitive bidding process. It is derived from the standpoint of a prospective bidder looking to participate in the tender. A fixed/forward contract is used along with the incoterms of buying the soybeans at the origin and selling/bidding them FOB ship. It is assumed that there are 4 competitors/rival bidders participating in the tender to make a total of 5 bidders. These bidders are said to be symmetric bidders, which means they all have the exact same obligations, cost structure and risk potential.

It is evident that each bidder won't bid at or below the derived cost due to the fact that there would be zero profit margin for the tender and no incentive for them to submit a bid. To best represent a real-life competitive bidding scenario, a distribution was created to derive a bid value above cost for each competitor. A normal distribution was used with a mean of 2% over cost and standard deviation of 5 cents/bu. Because international soybean import tenders are so privatized, it is difficult to gather any type of data to represent the behavior of competitor bidding. Therefore, a distribution was created to best represent bidding competitiveness in relation to a real-life competitive bidding scenario.

Models created in previous studies with no observed data use a similar procedure. A study performed by Takano et al. (2018), assumes a uniformly distributed estimation error for rival bids. The study also mentions that other previous literature assumes competitor estimation errors follow a Weibull or log-normal distribution. A study done by Shafahi and Haghani (2014), notes that if no historical rival bidding data is available, it is rational to assume that rivals will bid the same as an average bidder in that industry. They assume markup distributions follow a normal distribution with a variance derived from the industry in their study.

Costs are split up between known and unknown costs to form a combination of total costs represented for bid submission. In the base case, it is assumed that each rival along with the prospective bidder are 100% hedged in nearby soybean futures and their execution of the hedge is symmetrical as well. This means that there is no randomness in the cost of nearby futures and the value is symmetrical between all bidders. Another known cost that is assumed to be symmetrical between all bidders is that of the secondary rail market. Each participant is assumed to have participated in the secondary rail market opposed to the primary rail market and have covered their position to leave no risk exposure. The last two known costs used in the base case are the costs of margin at the origin and PNW. These are 10 cents/bushel and 3 cents/bushel, respectively. The unknown costs exemplified in the base case are origin basis, PNW basis, and the tariff value. The appropriate distributions along with correlations are used to represent each of these costs.

A simulation table of various bid values is used to show the expected profit at each bid and generate the optimal bid. For graphical representation, the first 10 values in the simulation table are set in 20 cent increments. The second set of values are set in 10 cent increments and the last set are 1 cent increments.

The third component in the profit function is the probability of winning. This is the percentage value that represents prospective bidder's probability of underbidding each rival, individually. An If Function is created to represent this probability and Monte Carlo Simulation is used at each bid level to determine that percentage. The function was set up so that if the rival's bid was greater than that of the prospective bidder, a value of 1 was returned. If the rival's bid was less than that of the prospective bidder, a value of 0 was returned. The mean value of the If Function is then recorded, and that value represents the probability of underbidding each respective rival.

For example, in a particular iteration of the model, if the prospective bidder's bid was lower than that of rival A's bid, then the potential bidder underbid rival A and "won" in that scenario. However, just because the potential bidder underbid rival A, doesn't necessarily mean he/she won the tender. In order to derive the probability of winning the tender, the probabilities of beating each rival are multiplied together to come up with one probability of winning the entire tender at that particular bid level. This derivation technique comes from Friedman's competitive bidding model.

The combination of the profit function (bid – cost) and probability of wining at a particular bid level results in the expected profit at that bid level. The bid with the highest expected profit is what determines the optimal bid for the tender. A total of 30 simulations are ran with 5,000 iterations each. This means that for each bid level, @Risk is running 5,000 iterations are completed to come up with an optimal bid, expected profit, and probability of winning the tender.

4.3. Cost of Demurrage

A measurement of demurrage is also derived in the model and is categorized as an unknown cost. It is not included in the base case, but its impact is exemplified in the sensitivity analysis on strategic variables. The cost of congestion in its entirety is extremely hard to measure and predict but can be a significant cost in competitive bidding.

As mentioned in chapter 2, queuing theory is one way in which congestion can be measured as a cost. Due to the lack of data and information, queuing theory was not able to be implemented in this model. However, the cost of congestion could not be ignored due to its significance on optimal bid derivation. To implement this impact, a cost termed ‘demurrage measurement’ is incorporated into the model. This cost consists of a probability, cost measurement, and representation of time the costs are incurred to formulate a final cost. Table 4.1 shows the appropriate variables and functions used to derive this cost.

Table 4.1. Demurrage Measurement

Variable	Function
Probability of Occurrence	=RiskBernoulli(X%)
Cost Measurement	=RiskUniform(18,000;25,000)
Days Late	=RiskUniform(1,8)
Cost of Congestion	=Probability*Cost*DaysLate

The RiskBernoulli function was chosen because this is the best way to represent a discrete event with a given probability. Either congestion happens, or it does not with a given probability of occurrence (50% and 90% are the probabilities used in this study). A RiskUniform distribution is used to actually measure the demurrage cost. The numbers used in the distribution ($18,000 and $25,000) are estimates from grain traders that participate in international trade and are aware of vessel demurrage penalties. To represent the days in which demurrage is incurred, a RiskUniform distribution is used starting at 1 day and ending at 8 days. Lastly, the cost of congestion is simply the product of the 3 variables. This number is then converted to $/bushel to be synonymous with the other cost measurements in the model.

4.4. Alternative Specification

Value at Risk (VaR) analysis is used to create an alternative specification in the optimal bidding model which assists with risk quantification and risk management practices. VaR is a powerful tool that has only recently been introduced to competitive bidding literature. Takano, Ishii and Muraki (2014), introduced VaR into their competitive bidding model. A majority of previous competitive bidding literature focused primarily on profit maximization in combination with optimal bid derivation. Risk exposure due to uncertainty was neglected, which creates an environment for profit loss exposure for bidders. Takano, Ishii and Muraki implemented a VaR constraint to nominally measure risk exposure and minimize potential loss while still defining an optimal bidding strategy. This measurement can be particularly useful in the competitive bidding process if a firm is looking to only expose themselves to a certain risk level.

Instead of using a simulation table of potential bid values in @Risk, another feature called RISKOptimizer is used to determine the VaR measurement. The RISKOptimizer model is setup to optimize the expected profit of the tender by adjusting the bid level. A range of various bid levels is used in the adjustable cell range to test the expected profit at each of those levels. The VaR measurement is implemented through a hard constraint on the optimization. This constraint is setup in the format of a percentile measurement. For example, if a prospective bidder wanted to be 95% certain that the most the firm could lose on the tender is 5 cents/bushel, the constraint would be setup as follows:

=RiskPercentile(Expected Profit, 0.05) >= -0.5

This uses a percentile measurement of the distribution of expected profit to determine the likelihood of a particular loss potential. This analysis is performed at various confidence intervals for both the lowest and highest risk situations.

4.5. Sensitivity Analysis

Sensitivity analysis is performed on strategic variables to showcase the effects of strategic variables on the optimal bid. The important concept at hand in the sensitivity analysis is that firms may take alternative strategies in competitive bidding, which would result in asymmetric costs and have an impact on the optimal bid for the prospective bidder. Rivals cannot observe the strategic play by each competitor prior to the bid submission, so strategic sensitivity analysis is crucial to understanding the impact certain variables have on the optimal bid. Table 4.2 shows the variables on which sensitivity analysis is performed.

Table 4.2. Sensitivity Analysis Outline

Variable	**Base Case**	**Change**
Incoterm Variation	Buy Origin & Sell FOB Ship	Buy Delivered & Sell FOB Ship Buy Origin & Sell CIF Destination
Number of rivals	4 Rivals	2 Rivals & 6 Rivals
Standard deviation of rival bids	5%	1% & 10%
Variability in execution of futures	\$9.73/bushel (bu.)	Rival B – \$9.53 Rival C – \$9.48
Rail coverage	All participants covered in secondary rail market	Rival B & D covered in primary rail market
Change in data timeline	2015-2018 data	2013-2014 data
Demurrage measurement	0% probability of occurrence	50% & 90% probability of occurrence

Table 4.3 shows the relevant outputs to be evaluated as a result of the analysis. This analysis gives decision makers and prospective bidders the ability to see the impacts of each strategic variable and place themselves in a better position to succeed in the competitive bidding process.

Table 4.3. Outputs to be Evaluated

Base Case	**Sensitivities**
Optimal Bid	Optimal Bid
Probability of Winning Tender	Probability of Winning Tender
Expected Profit	Expected Profit
	Probability of Underbidding Certain Rivals

4.6. Data

A majority of the data collected for the model is historical cost data relating to the relevant costs within the supply chain. This data came from a few different industry sources and databases. All data is gathered and converted to a weekly format and is represented in US dollars/bushel. The reason the data is represented in a weekly format is because it is relevant for the timeline of the tendering process and also an accurate interval measure for demurrage representation. The list of supply chain variables is as follows:

- Nearby Soybean Futures
- Origin Basis (Jamestown, ND)
- Origin Elevator Margin
- Pacific Northwest (PNW) Basis
- PNW Elevator Margin
- Secondary Rail Market or Daily Car Value (DCV)
- Primary Rail Market
- Rail Tariff
- Demurrage
- Ocean Freight

The timeline for the data were strategically chosen to represent specific market conditions. The base case and most sensitivity analysis were performed using weekly data from

2015-2018. This timeline is not only the most relevant, but also has the best representation of normal market conditions. During the past 3 years, a majority of agricultural costs were relatively stable compared to the years 2013-2014. In order to represent optimal bidding under an increase in price volatility, sensitivity analysis was performed using weekly data from 2013-2014.

Figures 4.1-4.6 show a graphical representation of the historical timeline of respective supply chain costs. It is evident that starting in 2015, most of the costs have experienced less volatility compared to years past. When looking specifically at the years 2013-2014, it is evident in most of the figures below that there is a noticeable increase in volatility.

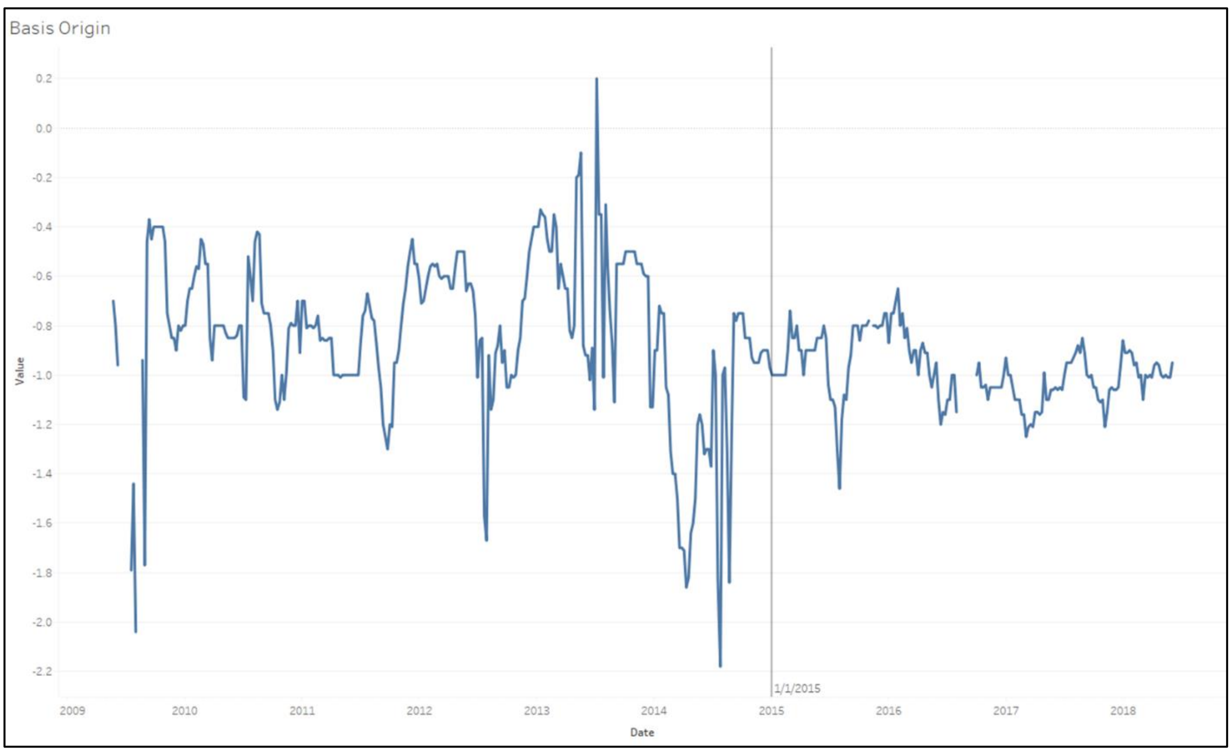


Figure 4.1. Historical Origin Basis

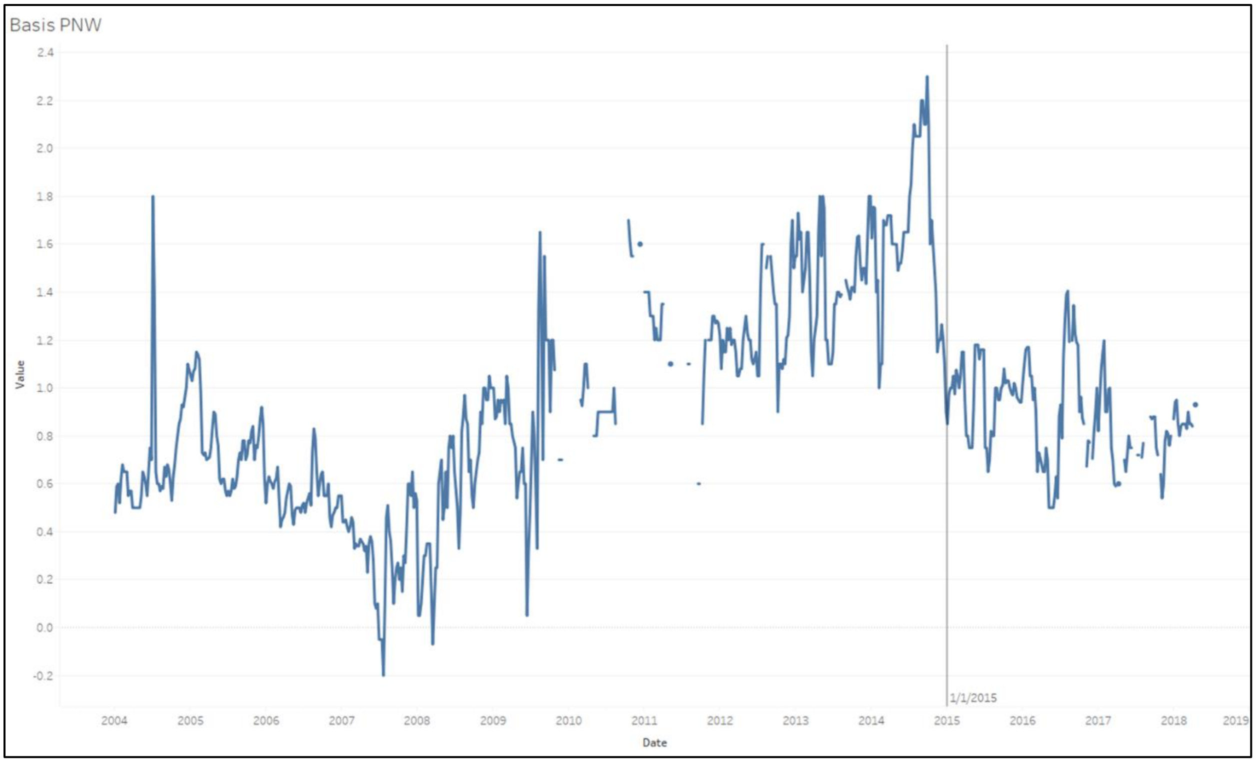


Figure 4.2. Historical PNW Basis Values

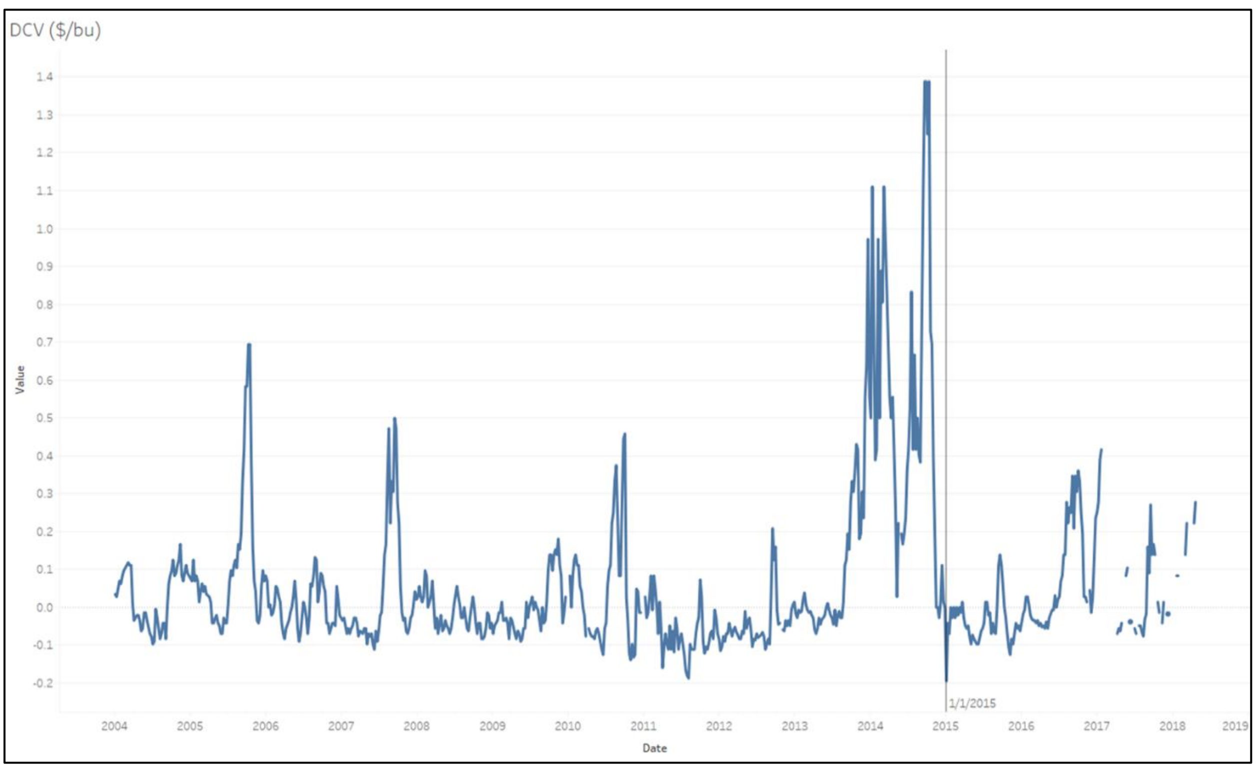


Figure 4.3. Historical Secondary Rail Market Values

Figure 4.4. Historical Nearby Soybean Futures Prices

Figure 4.5. Historical Ocean Freight Rates

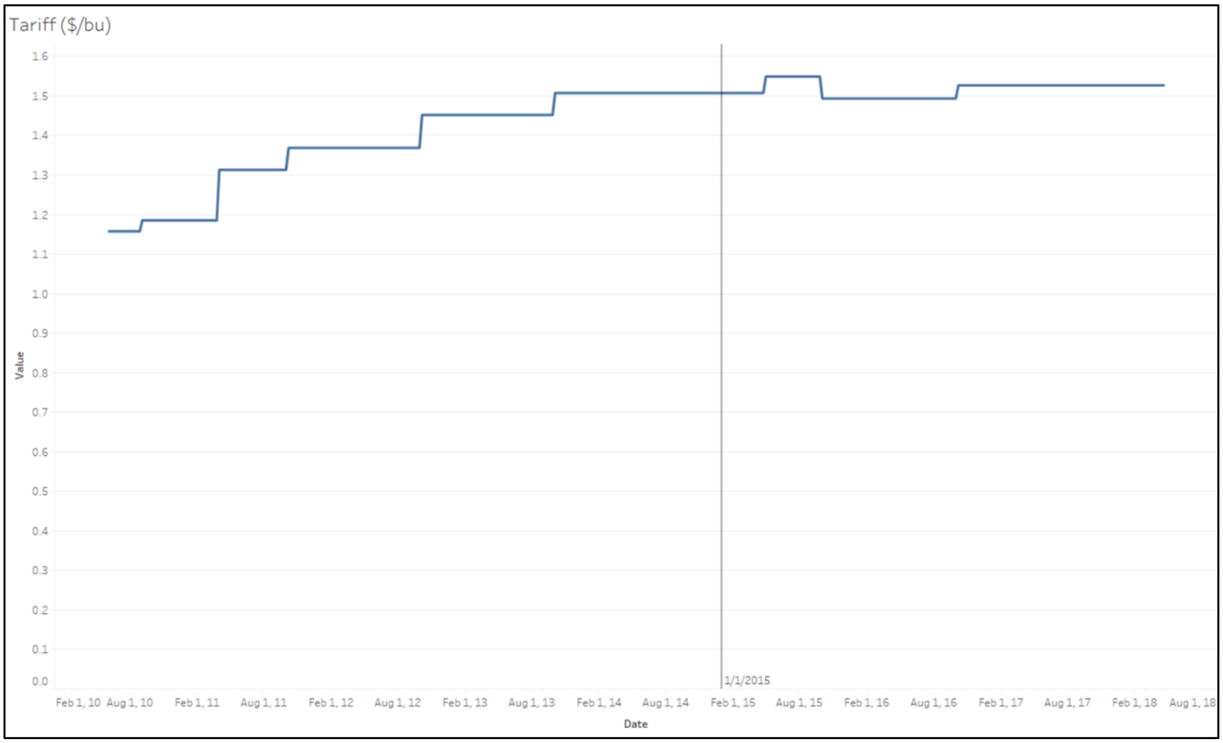


Figure 4.6. Historical Rail Tariff Rates

Nearby futures prices were gathered through DTN Prophet X. Historical basis values at the origin (Jamestown, ND) were also gathered through DTN Prophet X. Basis values at the PNW, secondary rail market values or daily car values (DCV), and ocean freight values were provided by Tradewest Brokerage Co. and gathered by Bruce Dahl. Data to represent the primary rail market and tariff values were developed by the BNSF Ag Commodity Unit and provided to Dr. Wilson. Vessel demurrage values were gathered from industry participants and a distribution of potential values was created to accurately represent demurrage. A constant number was used to represent elevator margin costs at the origin and PNW. These costs were gathered by Dr. Wilson through his working relationship with industry participants.

Probability density functions are gathered for each of the stochastic variables through the distribution fitting feature in @Risk. The stochastic variables used in the model are nearby soybean futures, origin basis, PNW basis, secondary rail market values, primary rail market values, tariff values, and ocean freight. @Risk has a feature within distribution fitting called ‘batch fit’ that will fit the data with the appropriate distribution and also create a correlation matrix to represent the correlation between each stochastic cost in the model. The distribution fitting analysis in @Risk fits the data to a set of predetermined distributions, and ranks each fit based on Akaike Information Criterion (AIC). Lastly, the correlation matrix is created for the entire data set.

Table 4.4 shows the best fit distribution chosen for each stochastic variable in the model along with the @Risk function used to represent the distribution and a graphical representation of each distribution. Distribution fitting of each stochastic variable allows for an accurate representation of the data through time and provides accurate means of capturing the price volatility of each variable. Rather than assuming a normal distribution for each variable or simply using deterministic values, the distribution fitting process in @Risk captures and exemplifies the true price volatility of each variable through time. Each distribution shown below is represented from 2015-2018 data. The same procedure was performed for the sentivity analysis using 2013-2014 data.

Table 4.5 shows the correlation matrix of the supply chain costs used in the model. This is another important input that has a significant effect on the optimal bid. Many of the supply chain costs experience volatility because of the same outside factors, whether it be due to weather, supply, demand, competition, etc. As a result, many of the supply chain costs become correlated both negatively and positively as can be seen in the table. Table 4.6 and 4.7 show the same content except using data from 2013-2014.

Table 4.4. Supply Chain Variable Distributions for 2015-2018 Data (@Risk)

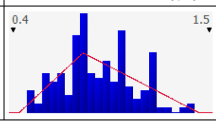
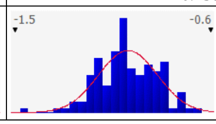
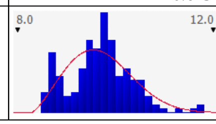
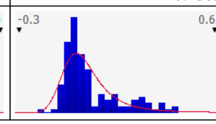
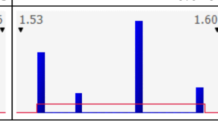
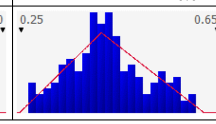
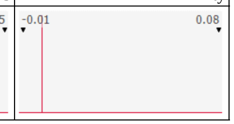
Name	Basis PNW	Basis Origin	NB Soybean Fut	DCV ($/bu)	Tariff ($/bu)	Ocean Freight ($/bu)	Primary ($/bu)
Best Fit (Ranked by AIC)	RiskTriang(0.45384,0.80000, 1.42730)	RiskNormal(-0.98091,0.13073)	RiskWeibull(2.3300,1.5495,RiskShift(8.3527))	RiskLogLogistic(-0.22127,0.22102,3.8466)	RiskUniform(1.536811,1.594618)	RiskTriang(0.25481,0.41590, 0.61819)	RiskLevy(-1.32343e-007,4.03965e-007)
Mean	0.8937	-0.9809	9.7256	0.0264	1.5657	0.4296	+Infinity
Mode	0.8	-0.9809	9.5707	-0.0288	1.5368	0.4159	2.312E-09
Median	0.8747	-0.9809	9.6766	-0.000243	1.5657	0.4265	7.556E-07
Std. Deviation	0.2014	0.1307	0.6257	0.1365	0.0167	0.0743	+Infinity
Graph							

Table 4.5. Supply Chain Variable Correlation Matrix for 2015-2018 Data (@Risk)

Correlation	Basis PNW	Basis Origin	NB Soybean Fut	DCV ($/bu)	Tariff ($/bu)	Ocean Freight ($/bu)	Primary ($/bu)
Basis PNW	1.000						
Basis Origin	0.504	1.000					
NB Soybean Fut	-0.267	-0.576	1.000				
DCV ($/bu)	0.169	-0.275	0.323	1.000			
Tariff ($/bu)	-0.163	-0.328	0.151	-0.055	1.000		
Ocean Freight ($/bu)	-0.290	-0.428	0.338	0.143	0.636	1.000	
Primary ($/bu)	0.314	-0.174	0.244	0.495	0.149	0.376	1.000

Table 4.6. Supply Chain Variable Distributions for 2013-2014 Data (@Risk)

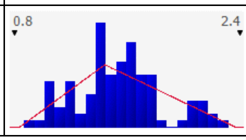
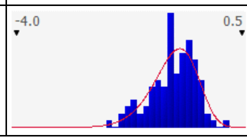
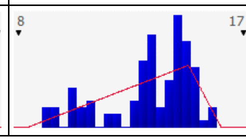
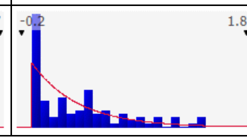
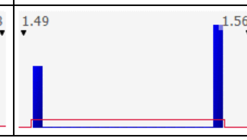
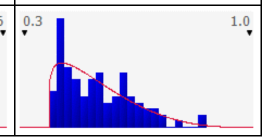
Name	Basis PNW	Basis Origin	NB Soybean Fut	DCV ($/bu)	Tariff ($/bu)	Ocean Freight ($/bu)
Best Fit (Ranked by AIC)	RiskTriang(0.86402,1.4500,2.3493)	RiskWeibull(7.3085,2.8613,RiskShift(-3.5679))	RiskTriang(8.5327,14.7400,16.0078)	RiskExpon(0.40074,RiskShift(-0.075282))	RiskUniform(1.493731,1.551983)	RiskBetaGeneral(1.1878,3.6959,0.38684,0.98147)
Mean	1.5545	-0.8854	13.0935	0.3255	1.5229	0.5315
Mode	1.45	-0.7636	14.74	-0.0753	1.4937	0.4256
Median	1.5321	-0.8465	13.3494	0.2025	1.5229	0.5097
Std. Deviation	0.3054	0.433	1.6331	0.4007	0.0168	0.1052
Graph						

Table 4.7. Supply Chain Variable Correlation Matrix for 2013-2014 Data (@Risk)

Correlation	Basis PNW	Basis Origin	NB Soybean Fut	DCV ($/bu)	Tariff ($/bu)	Ocean Freight ($/bu)
Basis PNW	1.000					
Basis Origin	-0.184	1.000				
NB Soybean Fut	-0.204	0.019	1.000			
DCV ($/bu)	0.521	-0.442	-0.444	1.000		
Tariff ($/bu)	0.359	-0.550	-0.538	0.766	1.000	
Ocean Freight ($/bu)	0.245	-0.617	-0.340	0.691	0.835	1.000

4.7. Summary

This chapter summarizes how a stochastic profit maximization model can be developed for optimal bid derivation. The empirical model is explained in detail, stochastic and fixed inputs are shown, and the data is explained along with its sources. The base case and each associated assumption is explained along with why certain assumptions had to be made. The development of the demurrage cost calculation is analyzed in each step along with an explanation of the VaR measurement and how it is derived. Lastly, sensitivity analysis is highlighted including the reason why each sensitivity is performed on the base case.

CHAPTER 5. RESULTS

5.1. Introduction

This chapter focuses strictly on the results of the model and the interpretations of them. First the base case is analyzed, and results are described. Then all sensitivity analysis is described in detail including the impact each analysis component has on the output variables. The added cost of demurrage is explained, and results are shown accordingly. Lastly, the alternative specification of VaR is revisited and results are explained in detail.

5.2. Base Case Results

The base case results are first split up into 3 different tables for graphical representation. Table 5.1 shows the results in 20 cent increments. Figure 5.1 shows the graphical layout of these results. Although this does not provide the optimal bid, it does show the behavior of each variable graphically which is significant. According to these results, the optimal bid will be around $11.50/bu. At that bid level, the probability of winning the tender is 13% with an expected profit of $0.02/bushel.

Figure 5.1, however, is more significant in this case. The graphical representation of these results shows very evidently that as the bid level increases, the probability of winning decreases. The PwTender curve starts off on a fairly flat level, decreases substantially and then flattens out again. This concludes that from $10.50-$10.90, the probability of winning is at or near 100%. This makes sense due to the fact that the initial cost combination of the base case scenario is $11.36/bu.

If all bidders are symmetric, the chance of any bidder submitting a bid less than that of their expected cost is negligible. Because all rival bidders are symmetric in the base case, the curves representing the probability of underbidding each rival individually are essentially stacked on top of on another which makes is difficult to differentiate each firm on the graph. It is obvious that the PwTender curve is quite a bit lower than that of the curves showcasing the probability of underbidding each rival individually. This shows that even though there is a 60% chance of underbidding each rival individually, the chance of winning the tender is still quite low. The profit line is simply a linear combination of each potential bid minus cost. It excludes the impact of the probability of winning.

The optimal bid can be observed graphically by finding the maximum of the Expected Profit curve. According to figure 5.1, it looks to be right around $11.50 which would match the results in table 5.1. Table 5.2 and figure 5.2 show the same results except in 10 cent increments. The optimal bid is unchanged along with the probability of winning and expected profit.

Table 5.3 and figure 5.3 represent the optimal bid when broken down into 1 cent increments. The optimal bid is $11.48/bu. The probability of winning the tender at that bid level is 15% and the expected profit is $0.019/bu. The expected profit may seem like a minimal value, but when participating in an international tender, bid submissions are usually for a volume of 70,000 metric tons or the equivalent to a vessel. This would equate to a profit of $0.70/metric ton or $48,864.

Table 5.1. Base Case Results in 20 Cent Increments

Bid Level	PwA	PwB	PwC	PwD	PwTender	Profit	Expected Profit
$10.50	100%	100%	100%	100%	100%	($0.86)	($0.86)
$10.70	100%	100%	100%	100%	100%	($0.66)	($0.66)
$10.90	100%	100%	100%	99%	98%	($0.46)	($0.45)
$11.10	96%	96%	96%	96%	85%	($0.26)	($0.22)
$11.30	83%	82%	83%	82%	47%	($0.06)	($0.03)
$11.50	60%	60%	60%	60%	13%	$0.14	$0.02
$11.70	34%	34%	35%	35%	1%	$0.34	$0.00
$11.90	16%	16%	16%	16%	0%	$0.54	$0.00
$12.10	5%	5%	5%	5%	0%	$0.74	$0.00
$12.30	1%	1%	1%	1%	0%	$0.94	$0.00

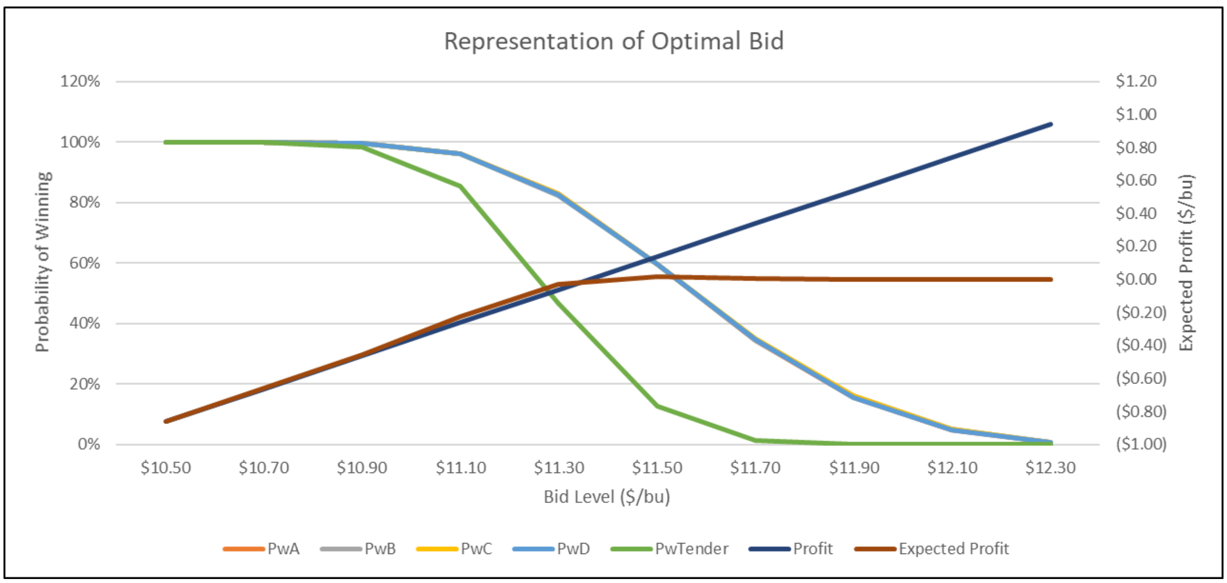


Figure 5.1. Base Case Results in 20 Cent Increments

Table 5.2. Base Case Results in 10 Cent Increments

Bid Level	PwA	PwB	PwC	PwD	PwTender	Profit	Expected Profit
$11.00	98%	99%	99%	98%	94%	($0.36)	($0.34)
$11.10	96%	96%	96%	96%	85%	($0.26)	($0.22)
$11.20	91%	91%	91%	91%	68%	($0.16)	($0.11)
$11.30	83%	82%	83%	82%	47%	($0.06)	($0.03)
$11.40	72%	72%	72%	72%	27%	$0.04	$0.01
$11.50	60%	60%	60%	60%	13%	$0.14	$0.02
$11.60	46%	46%	47%	47%	5%	$0.24	$0.01
$11.70	34%	34%	35%	35%	1%	$0.34	$0.00
$11.80	25%	24%	24%	24%	0%	$0.44	$0.00
$11.90	16%	16%	16%	16%	0%	$0.54	$0.00

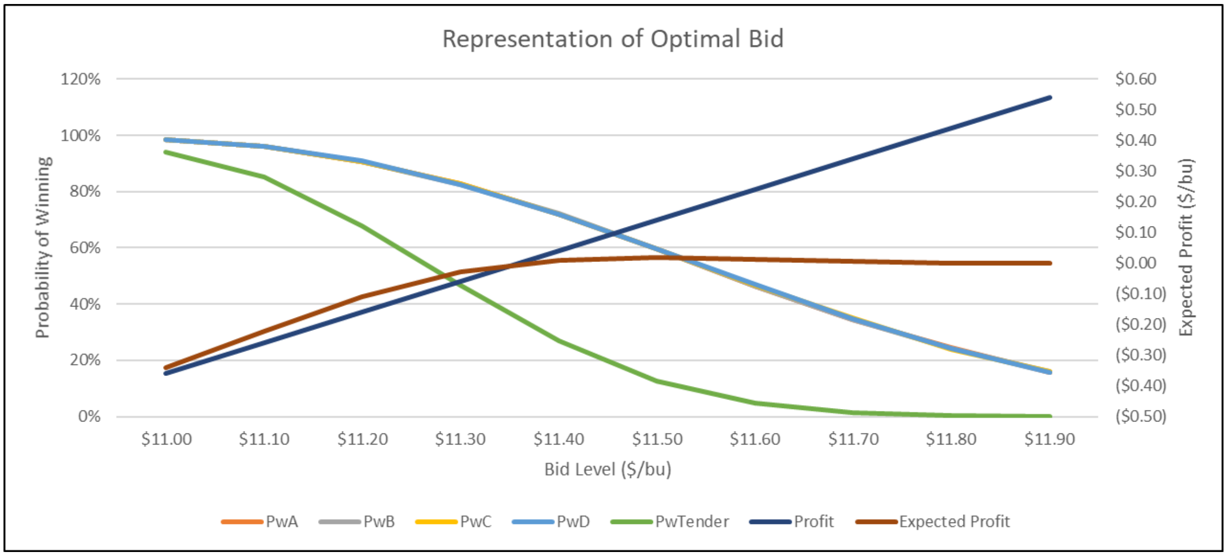


Figure 5.2. Base Case Results in 10 Cent Increments

Table 5.3. Base Case Results in 1 Cent Increments

Bid Level	**PwA**	**PwB**	**PwC**	**PwD**	**PwTender**	**Profit**	**Expected Profit**
$11.45	66%	66%	66%	66%	19%	$0.09	$0.017
$11.46	65%	65%	65%	65%	18%	$0.10	$0.018
$11.47	63%	64%	64%	64%	16%	$0.11	$0.018
$11.48	62%	62%	62%	62%	15%	$0.12	$0.019
$11.49	61%	61%	61%	61%	14%	$0.13	$0.018
$11.50	60%	60%	60%	60%	13%	$0.14	$0.018
$11.51	58%	58%	59%	58%	12%	$0.15	$0.017
$11.52	57%	57%	57%	57%	11%	$0.16	$0.017
$11.53	56%	56%	56%	56%	10%	$0.17	$0.017
$11.54	54%	55%	55%	54%	9%	$0.18	$0.016

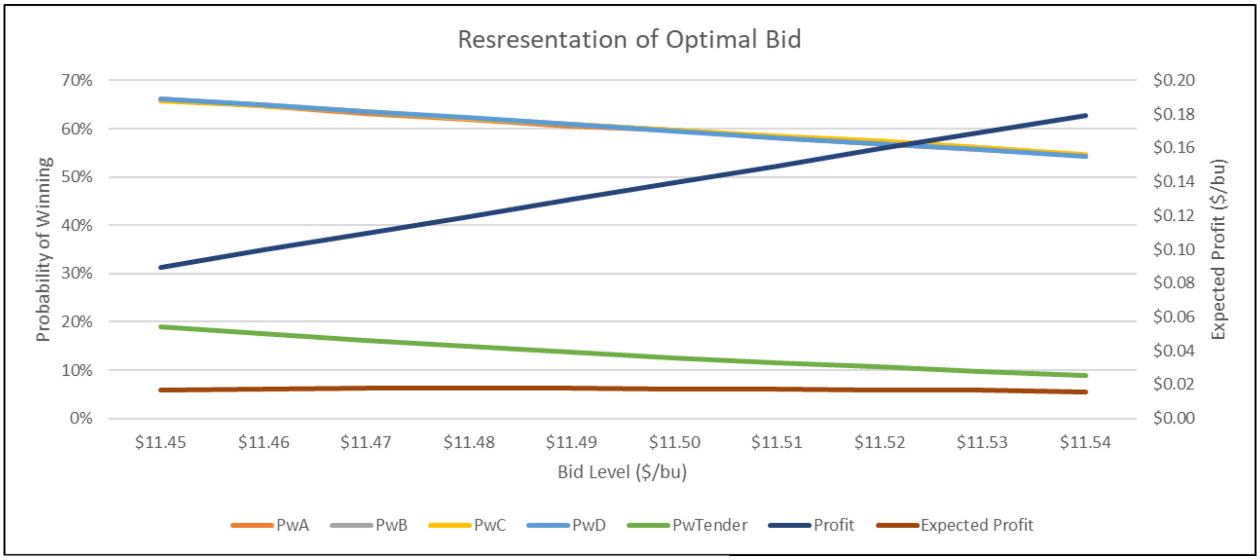


Figure 5.3. Base Case Results in 1 Cent Increments

Figure 5.4 showcases the impact of each stochastic input variable on the output value of the base case. The simulation with the optimal bid of $11.48 is chosen for this figure. PNW basis is the input with the most impact on profit followed by origin basis and tariff value. This is an important takeaway for prospective bidders, because it exemplifies the impact that each input has on the output value. This gives decision makers the ability to understand exactly which inputs are the major drivers and which have the least influence on overall expected profits.

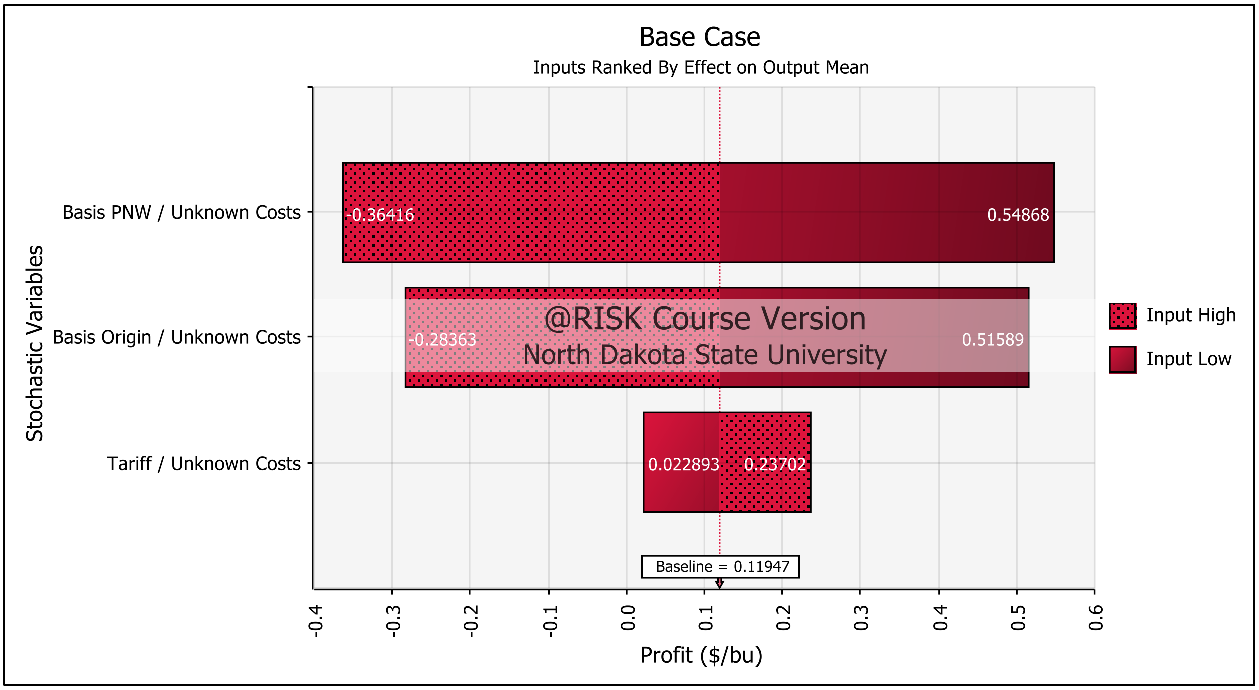


Figure 5.4. Impact of Key Inputs on Output Value (@Risk)

5.3. Sensitivity – Buy delivered & sell FOB ship

Table 5.4 and figure 5.5 depict the results of the sensitivity analysis on incoterm variation. Table 5.4 is in 1 cent increments and figure 5.5 is in 20 cent increments for graphical representation purposes. Instead of purchasing the soybeans from the origin, the soybeans are bought delivered and the selling/bidding price is FOB ship. Similar to the base case, 4 rivals are assumed to participate along with all of them being symmetric bidders. The rival's bids are 2% over cost with a standard deviation of 5 cents. Due to the change in incoterms, the input variables are not the same as the base case. Because the procurement of the soybeans is at the delivered phase of the supply chain, origin basis, origin margin, and rail transportation costs are not included. This exposes the bidder to less risk potential for optimal bid derivation.

Table 5.4. Sensitivity – Buy Delivered & Sell FOB Ship

Bid Level	PwA	PwB	PwC	PwD	PwTender	Profit	Expected Profit
$10.70	75%	75%	76%	76%	32%	$0.05	$0.016
$10.71	74%	74%	75%	74%	30%	$0.06	$0.018
$10.72	72%	73%	73%	73%	28%	$0.07	$0.020
$10.73	70%	71%	72%	71%	25%	$0.08	$0.020
$10.74	69%	69%	70%	69%	23%	$0.09	$0.021
$10.75	67%	67%	68%	68%	21%	$0.10	$0.022
$10.76	65%	64%	66%	66%	18%	$0.11	$0.020
$10.77	64%	63%	63%	64%	16%	$0.12	$0.019
$10.78	62%	62%	61%	62%	14%	$0.13	$0.019
$10.79	61%	60%	59%	59%	13%	$0.14	$0.018

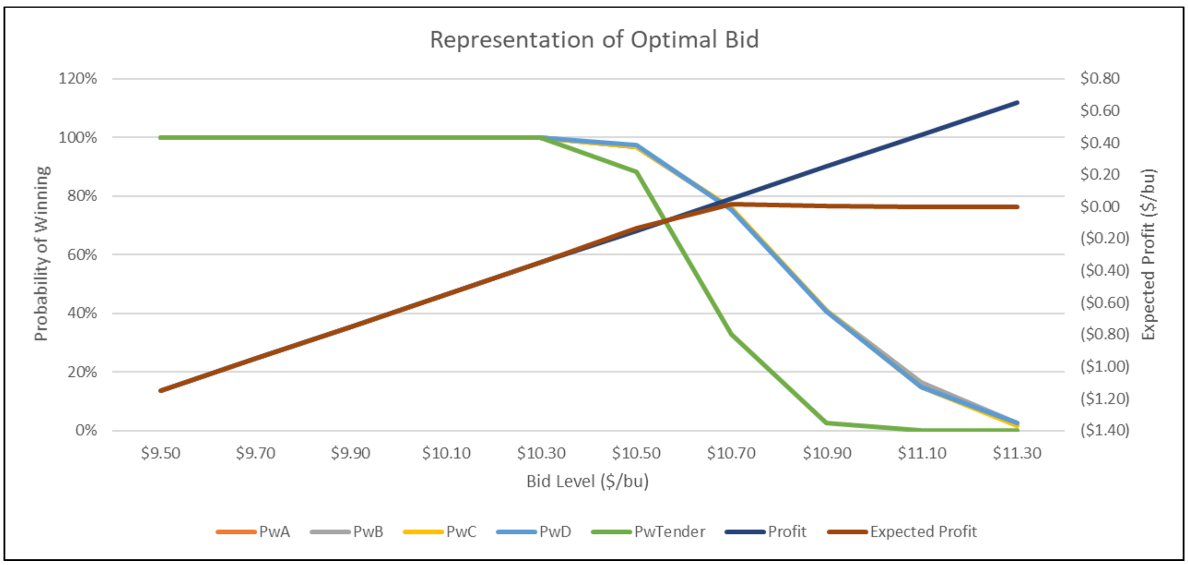


Figure 5.5. Sensitivity – Buy Delivered & Sell FOB Ship

The optimal bid in this case is $10.75 with a 21% probability of winning the tender and an expected profit of $0.022/bu. As expected, a less complex and lower valued cost structure results in a lower optimal bid. However, it is interesting that the probability of winning in this case is 6% more than that of the base case. Expected profits are also slightly greater compared to the base case. This proves that the less uncertainty there is about rival bids along with the prospective bidder's cost structure, the higher the profit potential and probability of winning. Because all rivals act as symmetric bidders in this case, it can be assumed that the cost structure of the rivals is also of lesser value and lesser risk exposure than that of their cost structure in the base case.

The mean value of the cost structure for the potential bidder in this scenario is $10.65/bu. It can be observed in figure 5.5 that the expected profit falls in line with the linear profit function up until about $10.70. This would make sense given the prospective bidder's mean cost value. The only stochastic variable included in the derivation of cost in this case is the PNW basis. Nearby futures and margin at the PNW are both fixed values. This means that 100% of the randomness in the cost derivation for the prospective bidder is caused by volatility in the PNW basis value.

5.4. Sensitivity – Buy Origin and Sell CIF Destination

Contrary to the strategic sensitivity analysis of buying delivered and selling FOB ship, this analysis includes more risk than that of the base case. In this case, the incoterms require the bidders to take on risk and cover costs of the product from origin to destination. It is again assumed that all bidders act symmetrically, and the rival bidders bid at 2% over cost with a standard deviation of 5 cents/bu.

Table 5.5 shows the results in 1 cent increments. Figure 5.6 shows the same results in 20 cent increments for better visual representation. It can be observed that in this case the optimal bid is $11.91/bu. This is 43 cents/bushel more than that of the base case. The probability of winning the tender in this case is 17% with an expected profit of $0.021/bu.

Table 5.5. Sensitivity – Buy Origin & Sell CIF Destination

Bid Level	PwA	PwB	PwC	PwD	PwTender	Profit	Expected Profit
$11.85	72%	72%	72%	72%	27%	$0.06	$0.016
$11.86	71%	71%	71%	71%	25%	$0.07	$0.018
$11.87	69%	70%	69%	69%	23%	$0.08	$0.019
$11.88	68%	69%	68%	68%	21%	$0.09	$0.019
$11.89	67%	67%	66%	67%	20%	$0.10	$0.020
$11.90	65%	66%	65%	65%	18%	$0.11	$0.020
$11.91	64%	64%	63%	64%	17%	$0.12	$0.021
$11.92	62%	63%	62%	63%	15%	$0.13	$0.020
$11.93	61%	61%	61%	61%	14%	$0.14	$0.019
$11.94	60%	60%	59%	60%	13%	$0.15	$0.019

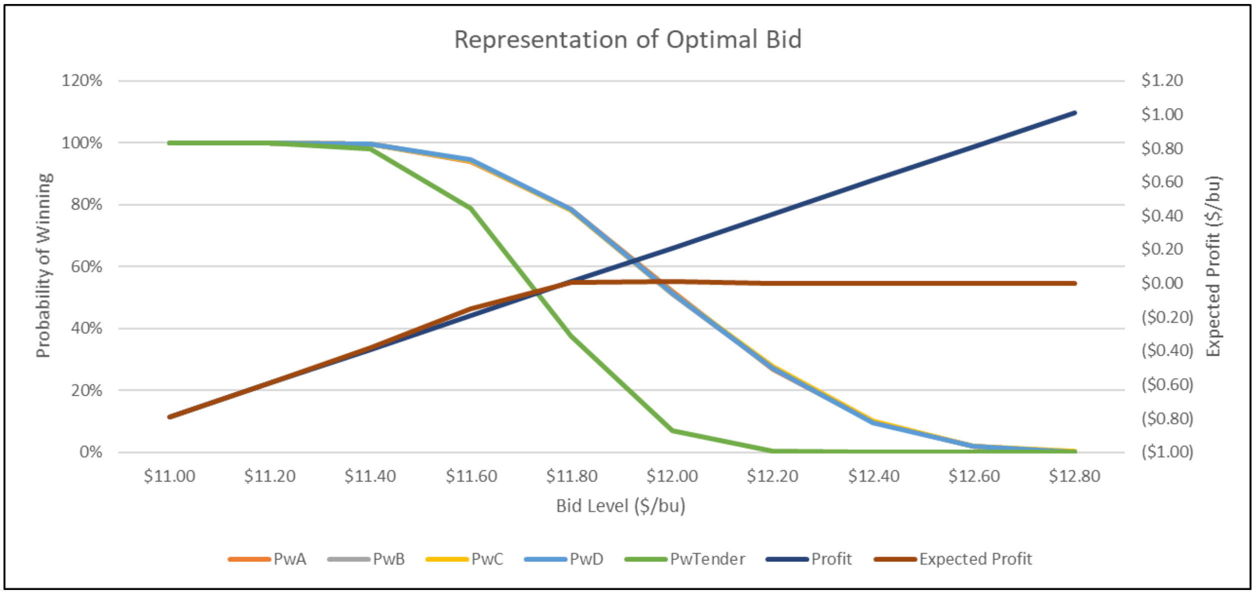


Figure 5.6. Sensitivity – Buy Origin & Sell CIF Destination

The probability of winning and expected profit in this case is slightly greater than that of the base case. Even though there is not much difference between the two, this could possibly be explained by the correlation that ocean freight has to other input costs along with the impact it has on the output value. The cost of ocean freight has a strong positive correlation with the tariff rate and nearby futures price. The correlations are 63% and 34%, respectively. The tariff is a stochastic variable used in the cost function. Ocean freight also has a strong negative correlation with the origin basis at 42%. Origin basis is another stochastic variable used in the cost function. Figure 5.7 shows the impact of the stochastic input variables on the output for this analysis. It can be observed that ocean freight has the second smallest impact on the output value. Although the impact of ocean freight is not as significant as that of the basis values, it is still important to be aware of the impact it has on the overall output.

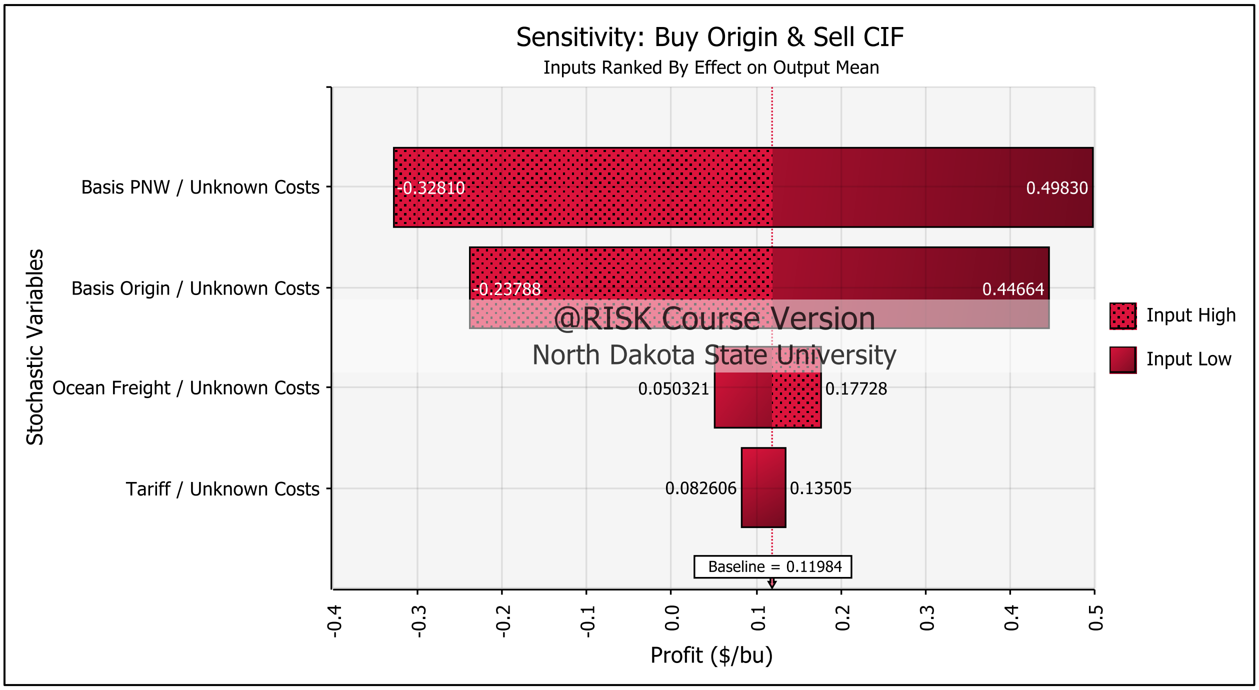


Figure 5.7. Impact of Ocean Freight on Output Value (@Risk)

5.5. Sensititvity – Change in Number of Rivals

In the base case it is assumed that the prosepective bidder is competing against 4 rivals. In all reality, without having any past data on soybean tenders and due to the privacy of the tender process in the real world, it is uknown exactly how many rivals prospective bidders may be competing against. To show the impact of a change in the number of rivals, optimal bids are derived with the prospective bidder competing against both 2 and 6 rivals.

All variables besides the number of rivals are the same as the base case. The bid submission is on the terms of buying at the origin and selling FOB ship. The rivals are bidding at 2% over cost with a standard deviation of 5 cents. The stochastic variables used in the cost derivation are origin basis, PNW basis, and tariff rate.

Table 5.6 shows the results of the tender when the prospective bidder is bidding against only 2 rivals. The optimal bid is $11.55/bu with an expected profit of $0.054/bu and a 28% probability of winning the business. Compared to the base case, the optimal bid in this scenario is 7 cents higher and the probabilty of winning is nearly doubled. An obvious takeway from this sensitivy analysis is that as the number of rivals decreases, the optmial bid increases and so does the probablity of winning. Because there wouldn't be as many competitors, there also wouldn't be as much uncertainty from the standpoint of the prosepective bidder. Figure 5.8 shows the graphical representation of the optimal bid derivation when the prosective bidder is competing against just 2 rivals.

Table 5.6. Sensitivity – Change in Number of Rivals to 2

Bid Level	PwA	PwB	PwTender	Profit	Expected Profit
$11.50	60%	61%	36%	$0.14	$0.050
$11.51	58%	59%	34%	$0.15	$0.051
$11.52	57%	57%	32%	$0.16	$0.052
$11.53	55%	56%	31%	$0.17	$0.052
$11.54	54%	55%	30%	$0.18	$0.053
$11.55	53%	53%	28%	$0.19	$0.054
$11.56	51%	52%	27%	$0.20	$0.053
$11.57	50%	50%	25%	$0.21	$0.052
$11.58	49%	49%	24%	$0.22	$0.052
$11.59	47%	48%	23%	$0.23	$0.052

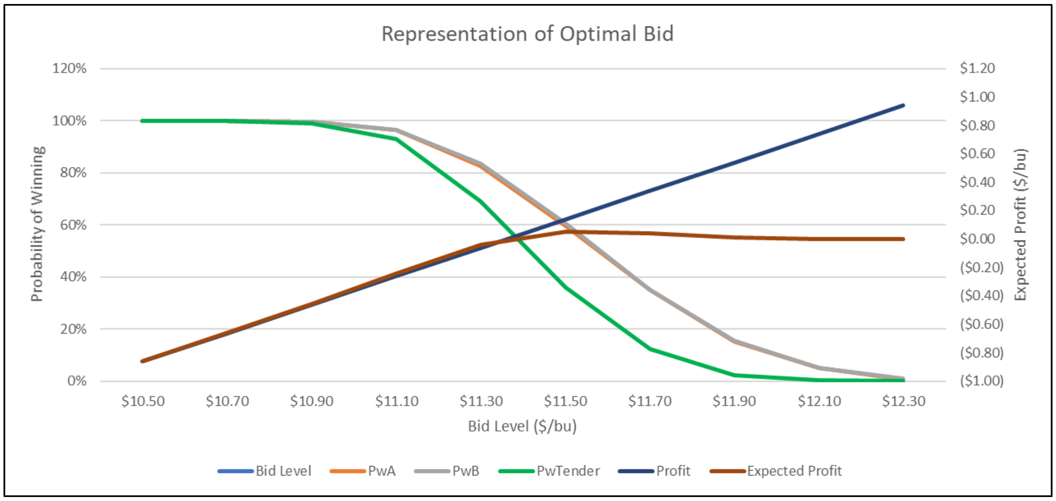


Figure 5.8. Sensitivity – Change in Number of Rivals to 2

Table 5.7 represents the results of the model when the prospective bidder is competing against 6 rivals. Contrary to the analysis of competing against 2 rivals, the optimal bid, probability of winning and expected profits decreased compared to the base case results. This can be expected given the logic of why the optimal bid increased when the number of rivals decreased. The optimal bid in this case is $11.46/bu with an expected profit of $0.009/bu and an 8% chance of winning the tender. The optimal bid decreased 2 cents compared to the base case, the probability of winning was about cut in half and the expected profit decreased by 1 cent or the equivalent of $25,718 if submitting a bid for a 70,000 metric ton vessel. Figure 5.9 shows a graphical representation of the optimal bid in this case.

The probability of underbidding each rival individually remained the same as the base case, but due to the increase in number of bidders, the probability of winning the tender along with expected profits decreased. With each addition of another competitor, not only is one more bid being submitted, but more risk is being introduced into the model.

The main takeaway from the sensitivity analysis of a change in the number of rivals is that it indeed does have a significant impact on the optimal bid, probability of winning and expected profit. Without previous tender data and knowing the behavior of rival bidding activity, it is unknown exactly how many rivals will participate in the import tender. However, this sensitivity analysis provides an idea of the impact each additional rival may have on the optimal bid.

Table 5.7. Sensitivity – Change in Number of Rivals to 6

Bid Level	PwA	PwB	PwC	PwD	PwE	PwF	PwTender	Profit	Expected Profit
$11.45	67%	66%	66%	67%	66%	67%	9%	$0.09	$0.008
$11.46	66%	65%	65%	66%	64%	66%	8%	$0.10	$0.009
$11.47	65%	64%	64%	64%	63%	65%	7%	$0.11	$0.008
$11.48	63%	62%	62%	63%	62%	63%	6%	$0.12	$0.007
$11.49	62%	61%	61%	61%	61%	62%	5%	$0.13	$0.007
$11.50	60%	59%	60%	60%	60%	61%	5%	$0.14	$0.006
$11.51	59%	57%	58%	58%	58%	60%	4%	$0.15	$0.006
$11.52	58%	57%	57%	57%	57%	57%	3%	$0.16	$0.005
$11.53	56%	55%	55%	55%	55%	56%	3%	$0.17	$0.005
$11.54	54%	54%	54%	53%	54%	54%	2%	$0.18	$0.004

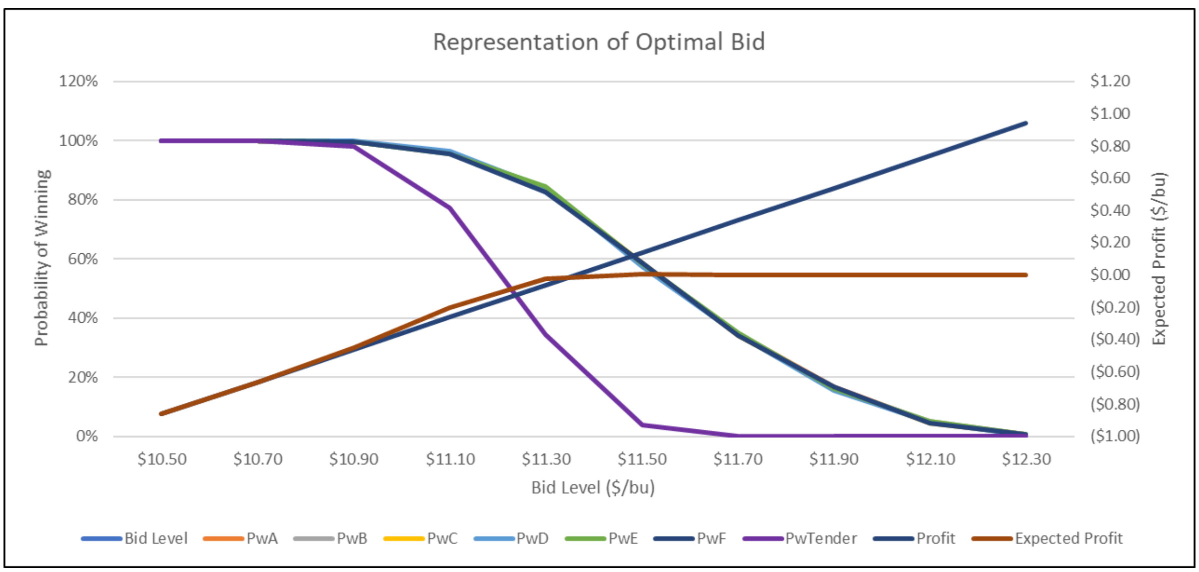


Figure 5.9. Sensitivity – Change in Number of Rivals to 6

5.6. Sensitivity – Change in Standard Deviation of Rival's Bids

One way in which randomness from rival bidders can change is through an increase or decrease in the standard deviation of their bid functions. The standard deviation represents the uncertainty or risk in the rivals bid derivation. Although the prospective bidder may have an idea of what the rivals cost functions are like, he/she may not know how they will behave in respect to bid markup values.

In the base case, it is assumed that all rivals bid at 2% above cost with a standard deviation of 5 cents. Just as in previous literature on competitive bidding, a normal market markup value was chosen. This markup value is the best estimate that the prospective bidder can assume without knowing the exact behavior of rivals or without having any previous tender data on their bidding behavior. It is, however, important to know the impact of which a change in the standard deviation of rival's bid functions can have on the optimal bid of the prospective bidder. To show this impact, sensitivity analysis is performed with rival's bid functions having a standard deviation of both 1 cent and 10 cents. All variables besides the standard deviation of rival bids are equivalent to the base case.

Table 5.8 represents the results when a standard deviation of 1 cent/bu for rival bids is implemented into the model. The optimal bid does not change relative to the base case. The probability of wining the tender increases by 1% and expected profit slightly increases as well. Less variability in the rivals bid functions means that the prospective bidder is exposed to less risk, and therefore will have a slightly higher probability of winning the tender. Although the results do not pose a dramatic change compared to the base case, it is important to note that less uncertainty in rival bid functions increases the probability of winning along with expected profits by a slight margin.

Table 5.8. Sensitivity – Change in Standard Deviation of Rival Bids (1 cent)

Bid Level	PwA	PwB	PwC	PwD	PwTender	Profit	Expected Profit
$11.45	67%	66%	67%	67%	20%	$0.09	$0.018
$11.46	65%	66%	65%	66%	18%	$0.10	$0.018
$11.47	64%	65%	64%	64%	17%	$0.11	$0.019
$11.48	64%	63%	63%	63%	16%	$0.12	$0.020
$11.49	62%	61%	61%	62%	14%	$0.13	$0.019
$11.50	60%	60%	60%	60%	13%	$0.14	$0.018
$11.51	59%	59%	59%	58%	12%	$0.15	$0.018
$11.52	57%	57%	57%	57%	11%	$0.16	$0.017
$11.53	56%	55%	56%	56%	10%	$0.17	$0.016
$11.54	54%	54%	54%	55%	9%	$0.18	$0.016

Table 5.9 depicts the results of the model when a standard deviation of 10 cents/bu is implemented. The optimal bid was, again, unchanged compared to the base case scenario. The probability of winning the tender was also equivalent to that of the base case. The expected profit was slightly less than that of the base case, but only by $0.001/bu. These results suggest that a 5% increase in the standard deviation of the rival bid functions does not have a significant effect on the optimal bid or probability of winning and just a slight decrease in the expected profit.

Table 5.9. Sensitivity – Change in Standard Deviation of Rival Bids (10 cents)

Bid Level	PwA	PwB	PwC	PwD	PwTender	Profit	Expected Profit
$11.45	66%	65%	66%	66%	18%	$0.09	$0.017
$11.46	64%	65%	65%	64%	17%	$0.10	$0.017
$11.47	63%	63%	63%	63%	16%	$0.11	$0.017
$11.48	62%	62%	62%	62%	15%	$0.12	$0.018
$11.49	60%	61%	61%	60%	14%	$0.13	$0.017
$11.50	59%	60%	60%	59%	13%	$0.14	$0.017
$11.51	58%	58%	58%	58%	11%	$0.15	$0.017
$11.52	57%	57%	57%	57%	10%	$0.16	$0.017
$11.53	55%	56%	56%	56%	10%	$0.17	$0.016
$11.54	54%	55%	55%	54%	9%	$0.18	$0.016

The results of the analysis done on the change in standard deviation of rival bid functions suggest that although there was a slight change in output, it was not as significant of a change compared to other sensitivity analysis done on the model. An increase (decrease) in uncertainty about the bid functions of rivals did result in a slight decrease (increase) in expected profits as expected. However, this did not have a significant enough impact that alter the optimal bid in either case.

5.7. Sensitivity – Asymmetric Bidding Environment

Another way in which randomness and uncertainty can be introduced by rivals is by strategic supply chain positioning for optimal bid derivation. Firms may take different strategies in cost valuation and bid derivation which would create an asymmetric bidding environment and rivals are not able to observe this. The strategic moves that firms can make to better position themselves are mainly done within the supply chain of costs from origin to destination. Firms can expose themselves to more risk on certain aspects of the supply chain while decreasing risk potential on other supply chain components. In the base case, it is assumed that all bidders act in an identical manner, whether that be strategic supply chain positioning or bid markup derivation. That may not always be the case in competitive bidding as each firm is constantly trying to strategically position themselves ahead of the competition.

To show the effect of an asymmetrical bidding environment on the prospective bidder's optimal bid, two different scenarios were explored. The first one introduces a variability in the execution of the soybean futures market hedge. In the base case, all rivals are assumed to be 100% hedged in the futures market at the mean value of $9.73/bu. For the sensitivity analysis, the assumption that all rivals are 100% hedged is still in place, but a variability in the execution of that hedge is changed for 2 rivals. Rival B's futures execution is 20 cents/bu lower than that of the base case and rival C's futures execution is 25 cents/bu lower than that of the base case.

Table 5.10 shows the results of the tender with this change in place. The optimal bid is decreased by 2 cents/bu, the probability of winning decreased to just 5% and the expected profit also decreased to $0.006/bu. More specifically, the probability of underbidding rival B at the optimal bid is only 38% compared to a 63% probability of underbidding rival A whom is assumed to behave symmetrically with the prospective bidder. The probability of underbidding rival C dropped to just 33%. The decrease in the chance of underbidding rivals B and C is the main driving force for the decrease in the probability of winning the tender and the noticeable decrease in expected profit. Figure 5.10 shows how the probability function of underbidding rivals B and C breakaway from the other bidders and drives down the probability of winning the tender.

Table 5.10. Sensitivity – Change in Rival's Execution of Futures

Bid Level	PwA	PwB	PwC	PwD	PwTender	Profit	Expected Profit
$11.45	64%	40%	33%	66%	6%	$0.09	$0.005
$11.46	63%	38%	33%	64%	5%	$0.10	$0.006
$11.47	62%	37%	32%	63%	5%	$0.11	$0.005
$11.48	61%	36%	30%	62%	4%	$0.12	$0.005
$11.49	60%	35%	29%	60%	4%	$0.13	$0.005
$11.50	59%	34%	29%	58%	3%	$0.14	$0.005
$11.51	57%	33%	28%	57%	3%	$0.15	$0.005
$11.52	56%	32%	28%	56%	3%	$0.16	$0.004
$11.53	55%	31%	26%	55%	2%	$0.17	$0.004
$11.54	54%	30%	25%	54%	2%	$0.18	$0.004

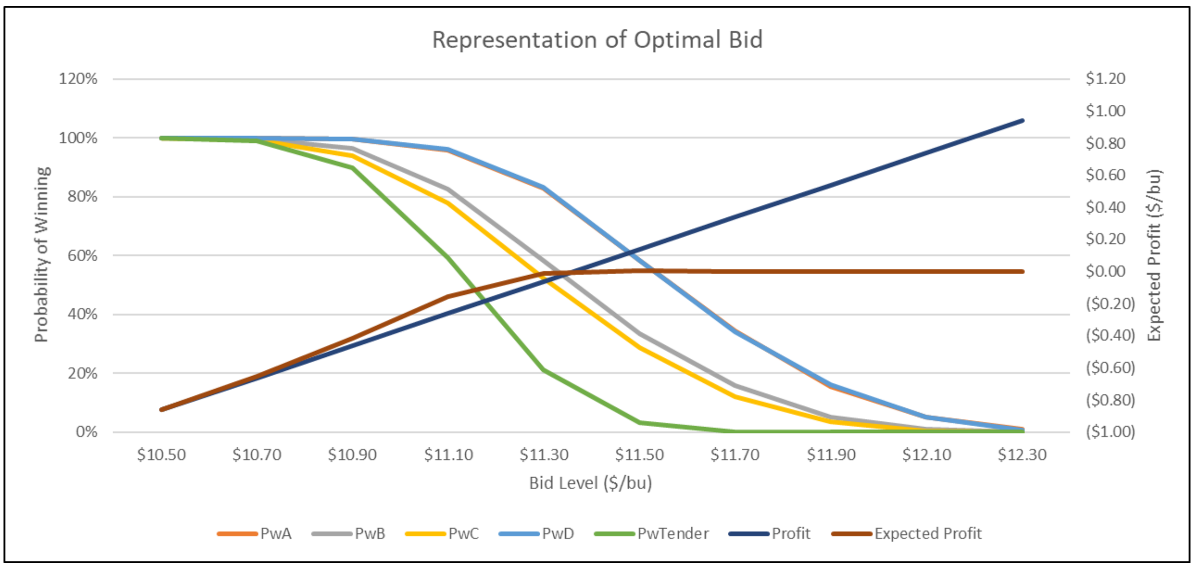


Figure 5.10. Sensitivity – Change in Rival's Execution of Futures

Firms can strategically position themselves to form a competitive advantage by participating in the primary rail market as opposed to the secondary rail market. Table 5.11 shows the results of the model when rivals B and D are covered in the primary market and rivals A and C are covered in the secondary market. The optimal bid decreases by 1 cent/bu. compared to the base case.

The probability of winning the tender also decreases by 1% and expected profits decrease slightly as well compared to the base case. The probability of underbidding the rivals that are covered in the primary market is slightly less than that of the rivals that are not at all bid levels. This is because coverage in the primary market, in this case, has less risk potential and volatility than coverage in the secondary market. This makes rivals B and D more competitive than they were in the base case and creates an asymmetrical bidding environment that has effects on the optimal bid for the prospective bidder. It should be noted that for this sensitivity, the use of the primary rail market excludes the prospective impact of velocity.

Table 5.11. Sensitivity – Change in Rival's Rail Coverage

Bid Level	PwA	PwB	PwC	PwD	PwTender	Profit	Expected Profit
$11.45	66%	63%	66%	62%	17%	$0.09	$0.015
$11.46	65%	61%	65%	61%	16%	$0.10	$0.016
$11.47	63%	60%	63%	60%	14%	$0.11	$0.017
$11.48	62%	59%	62%	59%	13%	$0.12	$0.016
$11.49	61%	57%	61%	57%	12%	$0.13	$0.016
$11.50	60%	56%	60%	56%	11%	$0.14	$0.016
$11.51	58%	55%	58%	55%	10%	$0.15	$0.015
$11.52	57%	54%	57%	54%	9%	$0.16	$0.015
$11.53	56%	52%	56%	53%	8%	$0.17	$0.014
$11.54	54%	51%	54%	51%	8%	$0.18	$0.014

The creation of an asymmetrical bidding environment does indeed have significant impacts on optimal bid derivation. Because rivals are unaware of competitor bidding behavior and strategic positioning, it makes it difficult for prospective bidders to position themselves strategically based on what they think rivals may or may not do for optimal bid formulation. However, it is important to realize the impacts that an asymmetrical bidding environment, whether it be because of contract price changes or a change in logistical risk coverage, can have on the optimal bid for a prospective bidder. This variability has proven to be more significant than that of a change in the standard deviation of rival bid functions. Figure 5.11 depicts a graphical representation of this environment.

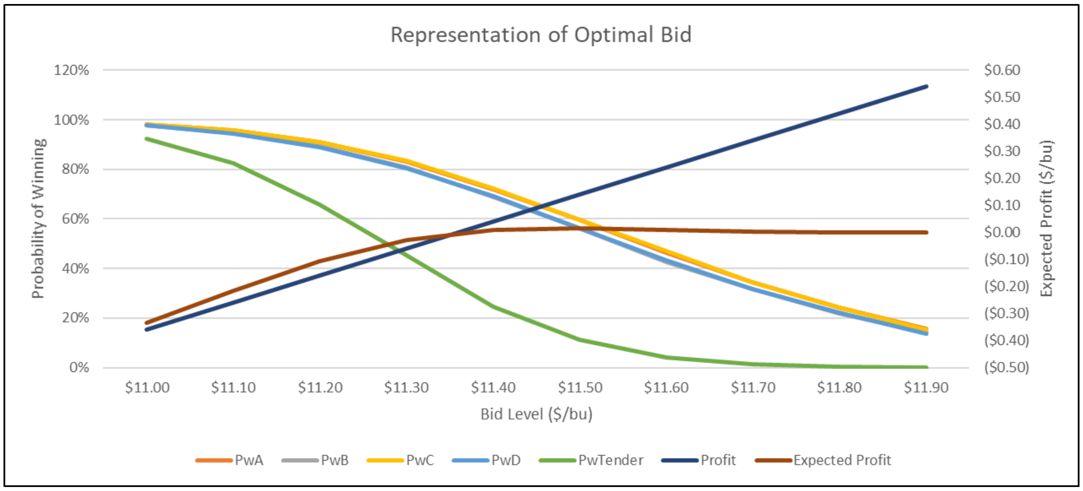


Figure 5.11. Sensitivity – Change in Rival's Rail Coverage

5.8. Sensitivity – Demurrage Measurement

An added cost that can be extremely significant and can determine the difference between indulging in a profit or experiencing the winner's curse is the cost of demurrage. When a supply chain runs efficiently with no bottlenecks, the cost of demurrage is of little concern. On the contrary, when bottlenecks are experienced within a supply chain, demurrage can quickly become a significant cost and if not accounted for can be detrimental to a firm's profits. However, it is difficult to accurately measure the cost of congestion. To account for the potential of an added cost of demurrage, the probability of occurrence at levels of 50%, and 90% were included in the model. All other variables remained synonymous to the base case. The added cost was not significant to the optimal bid at an occurrence under 50%. Results are shown below in table 5.12 for demurrage with a 50% chance of occurrence. The optimal bid increased by 2 cents/bu to $11.50/bu. The probability of winning the tender stayed the same and expected profit did as well. Figure 5.12 shows the impact of demurrage compared to other stochastic variables.

Table 5.12. Sensitivity – Demurrage Measurement (50% Occurrence)

Bid Level	PwA	PwB	PwC	PwD	PwTender	Profit	Expected Profit
$11.45	69%	68%	68%	68%	22%	$0.07	$0.016
$11.46	67%	67%	67%	67%	20%	$0.08	$0.017
$11.47	66%	66%	66%	66%	19%	$0.09	$0.018
$11.48	65%	65%	65%	65%	18%	$0.10	$0.018
$11.49	64%	63%	64%	63%	16%	$0.11	$0.018
$11.50	62%	62%	62%	62%	15%	$0.12	$0.019
$11.51	61%	61%	61%	61%	14%	$0.13	$0.018
$11.52	60%	59%	60%	59%	13%	$0.14	$0.018
$11.53	58%	58%	58%	58%	11%	$0.15	$0.017
$11.54	57%	56%	57%	57%	10%	$0.16	$0.017

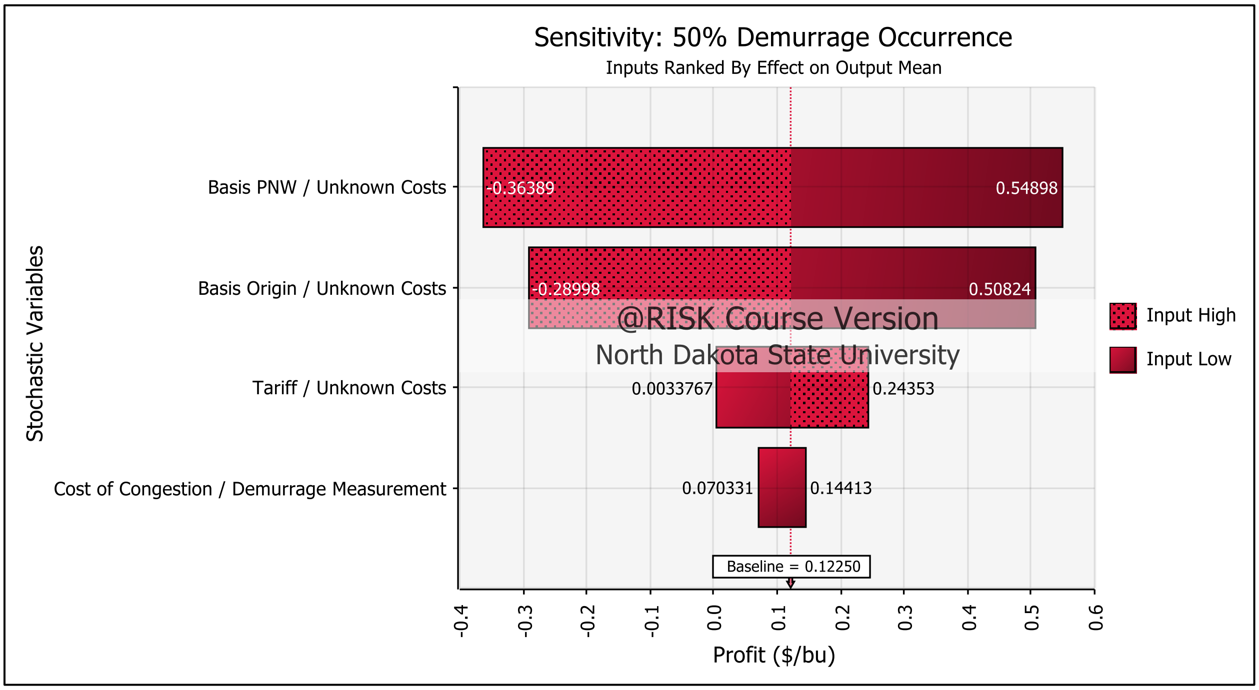


Figure 5.12. Impact of Demurrage Cost on Output Value (@Risk)

Table 5.13 shows the results when demurrage occurrence is set at a 90% probability. The optimal bid again increases by 1 cent/bu this time to $11.52/bu. The probability of winning decreased by 1% and the expected profit stayed the same as the sensitivity analysis performed with a demurrage occurrence of 50%.

Table 5.13. Sensitivity – Demurrage Measurement (90% Occurrence)

Bid Level	PwA	PwB	PwC	PwD	PwTender	Profit	Expected Profit
$11.45	71%	70%	70%	71%	25%	$0.05	$0.013
$11.46	69%	69%	69%	69%	22%	$0.06	$0.014
$11.47	68%	68%	68%	68%	20%	$0.07	$0.014
$11.48	67%	66%	66%	66%	18%	$0.08	$0.014
$11.49	65%	65%	65%	65%	17%	$0.09	$0.015
$11.50	64%	64%	64%	64%	16%	$0.10	$0.015
$11.51	63%	63%	63%	63%	14%	$0.11	$0.015
$11.52	62%	62%	61%	61%	13%	$0.12	$0.016
$11.53	60%	60%	60%	60%	12%	$0.13	$0.015
$11.54	59%	59%	59%	59%	11%	$0.14	$0.015

This added cost creates more uncertainty in optimal bid formulation with respect to the prospective bidder as well as his/her rivals. A majority of the time it may be uncertain if demurrage will occur, how long it will last, and what the value impacts could be for the firm. This is one way in which firms can account for that potential impact and this proves that at a probability of 50% occurrence or greater, demurrage will have a significant impact on the optimal bid. If demurrage was not accounted for, the optimal bid would be lower, and the prospective bidder would likely win the tender. However, that doesn’t necessarily mean the bidder would return a profit. He/she could experience the winner’s curse and win the tender but end up losing money for the firm due to demurrage penalties.

5.9. Sensitivity – Abnormal Market Conditions (2013-2014)

The final sensitivity performed on the model involves using supply chain cost data from the years 2013-2014. The reason this timeline was chosen for sensitivity analysis is because those 2 years were years of abnormal market conditions of extreme volatility. There were many outside factors that caused price volatility during those years. One of them mentioned in chapter 2 was the oil boom in western ND that increased rail prices. The BNSF rail line from ND to the PNW is crucial for soybean movement to make international trade successful. During the oil boom, the rail lines were over worked with oil trains and it became extremely hard to move grain. As a result, freight prices rose dramatically. This not only created extreme price volatility in both the primary and secondary rail markets, but also created demurrage penalties for market participants. Vessels were having to wait at the port for days at a time because the grain was not getting to the destination on time.

To show the impact of an increase in price volatility on the optimal bid, the base case model was ran identical to the original except instead of using data during a period of normal market conditions (2015-2018), data from 2013-2014 was used. Distributions and correlations were created for the new data set just as they were for the original data set. Table 5.14 shows the results of the optimal bid derivation with use of the new data. The optimal bid as a result of the model is $15.94/bu. with a 14% probability of winning the tender and an expected profit of $0.028/bu or $72,010 if submitting a bid for a 70,000 metric ton vessel.

Table 5.14. Sensitivity – Abnormal Market Conditions (2013-2014 Data)

Bid Level	PwA	PwB	PwC	PwD	PwTender	Profit	Expected Profit
$15.90	64%	64%	64%	64%	17%	$0.16	$0.026
$15.91	63%	63%	63%	63%	16%	$0.17	$0.027
$15.92	62%	62%	62%	62%	15%	$0.18	$0.027
$15.93	61%	62%	61%	62%	14%	$0.19	$0.027
$15.94	60%	61%	61%	61%	14%	$0.20	$0.028
$15.95	60%	60%	60%	60%	13%	$0.21	$0.027
$15.96	59%	59%	59%	59%	12%	$0.22	$0.027
$15.97	58%	58%	58%	59%	12%	$0.23	$0.027
$15.98	58%	58%	57%	58%	11%	$0.24	$0.026
$15.99	57%	57%	57%	57%	10%	$0.25	$0.025

The probability of winning in this scenario is almost the same percentage as that of the original base case. This shows that an increase in volatility doesn't necessarily have a dramatic impact on the probability of winning if all bidders are competing in the same bidding environment. However, due to an increase in prices and price volatility, expected profits rose compared to the original base case. This means an increase in volatility does create opportunity for increased profits. However, demurrage was not accounted for in this situation. As previously mentioned, this timeframe was a prime example of a peak demurrage potential that may have had detrimental impacts on firms bidding in international soybean tenders.

5.10. Alternative Specification – VaR Analysis

An important and impactful alternative specification is included in the model for risk management purposes. A VaR analysis is performed on the model in both low and high-risk situations to capture the ability to measure and manage potential loss while deriving optimal bids for international import tenders. As mentioned previously, VaR is a financial risk measure that is used to quantify the level of risk for a given situation. In the case of competitive bidding, VaR is implemented to measure the maximum loss potential for a firm looking to submit a bid in an international soybean tender. The incoterm with the lowest risk and uncertainty – buy delivered and sell FOB ship – and that with the highest level of uncertainty – buy origin and sell CIF destination – are used for VaR analysis. Table 5.15 shows the results of the VaR analysis performed on the low risk scenario.

Table 5.15. Alternative Specification – VaR Low Risk Situation

LOW RISK (Buy Delivered & Sell FOB Ship)			
Bid Level	**Confidence Interval**	**Expected Profit/Loss**	**VaR Result**
10.75	99%	-0.1	-0.0753
10.75	90%	-0.05	-0.0391
10.75	95%	-0.05	-0.0543
10.74	95%	-0.05	-0.044

First, Monte Carlo simulation is used to derive the optimal bid just as in the original base case scenario. After the optimal bid is derived, then the VaR analysis is implemented as explained previously in chapter 4. Results are derived for confidence levels of 90%, 95%, and 99%. With 99% confidence, the most the prospective bidder could lose at a bid level of $10.75/bu. is 7.53 cent/bu. At 90% confidence, the most the prospective bidder could lose at a bid level of $10.75/bu. is 3.91 cents/bu. This can also be interpreted as there being a 10% chance if the prospective bidder submits a bid of $10.75, he/she will lose more than 3.91 cents/bu.

Notice at the 95% confidence level there is an expected maximum loss target of 5 cents/bu. At a bid level of $10.75/bu, that maximum target is exceeded. The VaR result yields a potential loss of 5.43 cents/bu. If there was a requirement by a firm that stated they could not submit a bid with a VaR result exceeding potential loss of 5 cents/bu at 95% confidence, then the firm would be forced to decrease their bid to $10.74/bu. to meet that specification. That is an example of how VaR analysis can efficiently and effectively be implemented into the competitive bidding process.

Table 5.16 yields the results of the VaR analysis for the high-risk situation. They are similar to that of the low risk, except the optimal bid level is obviously different to accommodate for the higher cost values. The VaR result at 99% confidence is 1.5 cents closer to its constraint in the high-risk scenario compared to the low-risk scenario. Once again, the maximum potential loss was exceeded at the 95% confidence level and the optimal bid had to be decreased by 2 cents/bu. in order to meet that constraint. VaR analysis proves to be a powerful alternative specification that can be implemented into the optimal bid derivation process in order to accurately measure and manage potential uncertainty.

Table 5.16. Alternative Specification – VaR High Risk Situation

HIGH RISK SCENARIO (Buy Origin & Sell CIF Destination)			
Bid Level	**Confidence Interval**	**Expected Profit/Loss**	**VaR Result**
11.91	99%	-0.1	-0.09
11.91	90%	-0.05	-0.044
11.91	95%	-0.05	-0.058
11.93	95%	-0.05	-0.0451

5.11. Summary

The model in this study is created to address all uncertainty bidders are exposed to when participating in the competitive bidding process. Risk exposure comes from uncertainty in own costs, competitor costs, and competitor bid levels. Base case results are discussed in this chapter. The main output variables examined are optimal bid level, probability of winning, and expected profit. The implication of each result on the output variables is explained in the chapter. Lastly, results of the alternative specification are analyzed along with how the specification can be used for firm risk metric purposes.

CHAPTER 6. CONCLUSION

6.1. Introduction

This chapter revisits the problem statement and explains the issues faced by prospective bidders looking to participate in the competitive bidding process. A review of the background research is then summarized. The empirical model is described along with key results. Important implications from the results are included in this chapter. Lastly contributions to literature, limitations, and opportunities for further research are discussed.

6.2. Problem Statement

Although buyer's auctions prove to be an effective and efficient manner of conducting business, they can often pose uncertainty for sellers in a few different ways. In regard to privatized, sealed-bid tenders, prospective bidders are not aware of their competition at all. They do not know how many rivals they will be competing against, and they also do not know the cost structure of those rivals. The optimal bid for a prospective bidder will be altered based on the number of rivals alone. The rivals will also likely be strategically positioning themselves in a manner to try and gain a competitive advantage over the competition and this is something prospective bidders are not able to observe. This creates a framework of uncertainty that can be difficult to capture.

Another risk faced by prospective bidders is uncertainty around their own cost structure. Price volatility occurs throughout the supply chain at many stages. Whether that be in commodity procurement or logistics, costs are always changing, and market participants are faced with uncertainty due to the volatility of those costs. Unrecognized costs, such as demurrage penalties can also arise and have detrimental effects on firm profits.

A supply chain at an international level is susceptible to experience bottlenecks at some point. Where the bottlenecks occur, when they occur, and how long they last can often be hard to define. This creates rise to possible demurrage penalties which, depending on the contract terms, may have to be paid by the seller.

If a prospective bidder underestimates cost, he/she will likely be the lowest bidder and win the tender. However, if costs exceed revenue in the case of the tender, the bidder will lose money on the business transaction and experience the winner's curse. At the same time, sellers want to the lowest-cost supplier and win the business. If they are including a cost of congestion, they may overestimate cost in cases where demurrage penalties do not occur and end up bidding higher than rivals.

Another problem faced by prospective bidders involved in the competitive bidding process is the lack of an overall risk measurement to capture the exposure and potential profit and loss opportunity for a firm. Because the process of international tenders involves a large volume of a commodity to be traded, the slightest change in price at any stage can have a large impact on the sellers' profit potential. Previous literature does not include a way in which firms can measure overall risk exposure and interpret that exposure in a dollar amount. Lastly, optimal bid derivation for international import tenders is a complex framework that may be difficult for suppliers to understand. The risks and costs experienced throughout the supply chain can be difficult to encapsulate and include in optimal bid formulation.

6.3. Supply Chain Management in Agriculture Overview

Chapter 2 describes supply chain management in agriculture and its importance. A supply chain is depicted, and each element is described. The associated risks of each supply chain element are also explained and mitigation techniques for those risks are highlighted as well.

Important studies regarding supply chain uncertainty are described along with their results and implications. The flow of agricultural products throughout a supply chain is presented. The flow and processes of which commodities move throughout the supply chain is important for market participants to understand. With that, comes a better understanding of the supply chain risks that can arise.

The logistical rail cost and pricing mechanisms are also described in chapter 2. This includes pricing related to the tariff value, primary rail market and secondary rail market. The other logistical cost involved in the soybean supply chain is ocean freight.

A main focus of this study is that of congestion, the impacts it has, and measures that can be taken to account for it within the supply chain. Chapter 2 discusses previous literature on supply chain congestion modeling techniques. The chapter also highlights important and impactful industry examples of supply chain congestion along with the implications and lasting effects the congestion caused for market participants.

6.4. Competitive Bidding Overview

Chapter 3 focuses on explaining the competitive bidding process and its application to agriculture. Seminal work is first explained to set the stage for the evolution of the competitive bidding process. This includes studies by Friedman, Gates, Carr, and others. Although these studies are not directly tied to the agricultural industry, it is important to know the foundation of which competitive bidding evolved. This also shows that competitive bidding is a powerful business marketing technique that is used in many different industries such as construction projects and online product auctions.

Common auction types within the competitive bidding framework are discussed along with the differences between each auction type. A structured example of an international agricultural import tender process is explained in detail. The General Authority for Supply Commodities (GASC) is an economic entity in Egypt that structures and holds international wheat import tenders on a regular basis. Having access to information of this process helps shape the idea of what more privatized import tenders may be like. It also helps to build a picture of the competitive bidding process from start to finish.

In application to competitive bidding in agriculture, there were 3 studies examined. Crespi and Sexton (2004), performed a study on competitive bidding by analyzing the bidding behavior of beef processing plants that bid for cattle in the Texas Panhandle. Wilson and Dierson (2001), studied the strategic positioning of suppliers participating in international wheat import tenders. In the third study, Wilson and Dahl (2001), studied competitive bidding in the case of minor oilseeds. The application of competitive bidding in agriculture is important to examine in order to prove the many different ways in which this business marketing technique is implemented into the industry. Each implementation of competitive bidding in agriculture is unique to its underlying purpose or commodity, but all have many of the same foundational aspects that can be analyzed as a whole.

Lastly, a study of competitive bidding that included a value-at-risk (VaR) constraint was explained in detail. Takano, Ishii and Muraki (2014), developed a stochastic dynamic programming model to analyze competitive bidding. They included a VaR constraint in the model to measure potential risk exposure. The constraint proved to be significant in the model and was used as a risk measurement tool for potential loss exposure in the competitive bidding process.

6.5. Empirical Results

A stochastic profit-maximization model is the core framework of the model presented in this study. Historical industry cost data was collected, distributions were fit for each cost, and correlations were assigned between each cost variable. From there, the framework is set up to stochastically optimize expected profit for a given set of inputs. The framework stems from a profit function developed by Friedman:

$$E(x) = (X - C) \cdot P(x)$$

Where E(x) is the expected profit, X is the bid level submitted, C is expected cost and P(x) is the probability of underbidding all competitors.

The bid level associated with the maximum expected profit would be considered the optimal bid and should be the bid that the prospective bidder submits for the tender. Monte Carlo simulation is used to solve the model. A simulation table is created at various bid levels and 5,000 iterations are ran at each bid level to determine the optimal bid for the tender.

The base case scenario assumes symmetric bidding. 4 rivals are competing against a prospective bidder and all participants are assumed to have the same cost structure. The rivals bid formulation is 2% over cost with a standard deviation of 5 cents/bu. This creates a symmetric bidding environment in which sensitivity analysis can be conducted from. The incoterms for the base case scenario are buying the soybeans at the origin (ND) and selling/bidding them FOB ship. This means that the buyer would assume responsibility once the beans are loaded onto a vessel to be sent to a foreign destination.

Sensitivity analysis is then conducted on strategic variables included in the competitive bidding framework. The important concept overarching all of the sensitivity analysis procedures is that in this competitive bidding environment, firms are able to strategically place themselves in positions of leverage over competition and rivals are not able to do observe that. There is more than one way in which firms are able to do so and that is exploited in the analysis. The analysis also shows the impact that incoterm variation, change in the number of rivals, and costs of congestion can have on the optimal bid, expected profits and probability of winning. Lastly, an alternative specification of VaR analysis is included as a separate piece in the model. The VaR measure is set as a constraint on the optimization of expected profits in order to measure the potential loss that can be experienced due to uncertainty in the model.

The optimal bid in the base case scenario was $11.48/bu. with a 15% chance of winning the tender and an expected profit of $0.019/bu. This can be interpreted as if a prospective bidder were to bid $11.48/bu. there would be a 15% chance given the number of rivals and their cost structure is as assumed in the model, the prospective bidder would win the tender. If that were to happen, the prospective bidder would obtain an expected profit of $0.019/bu. or 70 cents/metric ton. Most tender bids are submitted on terms of a 70,000 metric ton vessel, so in that case the final expected profit would be $48,864. There were 3 stochastic variables included in the base case. They were:

1. PNW Basis
2. Origin Basis
3. Tariff Value

Of those 3 costs, the PNW basis had the greatest impact on the output followed by the origin basis and lastly the tariff value.

Results of all sensitivity analysis are displayed in table 6.1. The first sensitivity performed on the model was a variation in incoterms. The base case had incoterms of buying the soybeans at the origin and selling/bidding them FOB ship. The two other incoterms included in the sensitivity analysis are:

1. Buy Delivered & Sell FOB Ship
2. Buy Origin & Sell CIF Destination

All variables remained synonymous with the base case other than costs that needed to be changed to accommodate each incoterm variation. As expected, the first incoterm's optimal bid was less than that of the base case and the second incoterm's optimal bid was greater than that of the base case. This sensitivity showed the impact of a variation in buyer/seller cost and risk responsibility on the optimal bid.

The next sensitivity done on the base case model was a change in the number of rivals. Because most international import tenders are a privatized and operate with a sealed-bid procedure, it is impossible to know exactly how many competitors that prospective bidders will have. The results show the impact of a change in the number of rivals to the output variables. As expected, a decrease in number of rivals increases the optimal bid and an increase in number of rivals decreases the optimal bid. Just a cut and addition of 2 rivals relative to the base case resulted in significant impacts on the output variables.

A change in standard deviation of rival bid functions did not have a major impact on the output variables. However, it is still important to realize that asymmetric bidding does have an impact on results and should be taken into consideration when deriving an optimal bid. Without information on rivals or data of previous bidding behavior, this measurement is hard to gauge.

The other way in which an asymmetrical bidding environment can arise is through a change in cost structure of rivals. This was shown in analysis of changes in futures execution along with primary rail market coverage. The results yielded a more significant impact than those of a change in standard deviation of rival bid functions.

The analysis of demurrage penalties with probability of occurrence greater than 50% proved to have a significant impact on output variables. Even though this cost may be negligible a majority of the time, it is crucial to include in an optimal bidding estimation. This is a cost that if unaccounted for, could make the decision between slight profits and extreme losses. Lastly, sensitivity analysis was conducted using data representing abnormal market conditions. Results showed an optimal bid increase to account for increased cost estimation. The expected profit also increased, but probability of winning remained about the same.

Table 6.1. Sensitivity Analysis Summary

Sensitivity	Optimal Bid ($/bu)	Expected Profit ($/bu)	Probability of Winning (%)
BASE CASE	$11.48	$0.019	15%
Buy Delivered & Sell FOB Ship	$10.75	$0.022	21%
Buy Origin & Sell CIF Destination	$11.91	$0.021	17%
# of rivals = 2	$11.55	$0.054	28%
# of rivals = 6	$11.46	$0.009	8%
Standard Deviation of Rival Bid = 1 cent	$11.48	$0.020	16%
Standard Deviation of Rival Bid = 10 cents	$11.48	$0.018	15%
Change in Futures Execution by Rivals B & C	$11.46	$0.006	5%
Rivals B & D Covered in Primary Rail Market	$11.47	$0.017	14%
Demurrage – 50% chance of occurrence	$11.50	$0.019	15%
Demurrage – 90% chance of occurrence	$11.52	$0.016	13%
2013-2014 Market Conditions	$15.94	$0.028	14%

VaR analysis is utilized as an alternative specification on the optimal bidding model. The analysis is done in both a low and high-risk competitive bidding situation. The optimal bid is first derived for each scenario and then the VaR constraint is implemented. Results varied depending on the confidence level set in place. This measurement tool proves to be extremely impactful in measuring and managing overall uncertainty in competitive bidding. It can be utilized in a business environment as a risk metric in order to measure maximum loss and risk exposure. It is also easy to interpret and understand which makes it all the more useful for industry participants.

6.6. Implications of Results

It can be easy to get caught up in the specific value determination portions of this study without grasping the true takeaway and implications as a result of the study. This analysis was performed with the intention of precisely and accurately depicting a soybean supply chain from ND to Asia and implementing the elements of that supply chain into a competitive bidding model. Although the optimal bid value(s) of the base case and sensitivity analysis are important, the end goal was not to focus strictly on those values. Instead, this study was performed to provide information on strategic inputs, along with a well-defined model for optimal bid derivation to be used in agricultural import tenders. Competitive bidding on an international level in privatized tenders exposes bidder to a very dynamic and uncertain bidding environment. This study encapsulates the uncertainty involved in the process and draws conclusions for various bidding scenarios. An alternative specification of valued risk measurement is also included in the study to help with risk management.

The results indicate that a change in the number of rivals, change in incoterms, asymmetrical bidding environments, demurrage occurrence, and abnormal market conditions do indeed have a significant impact on the optimal bid for prospective bidders looking to participate in competitive bidding. The impact of each change in input to output variables varies as the results show.

The main implication that can be made for prospective bidders given the results is that in order to compete and succeed in competitive bidding, firms must either be low cost suppliers or differentiate themselves in such a way that they gain a competitive advantage over their rivals. Although the sensitivity analysis can provide insight into which variables create the most uncertainty and are the most impactful, there is no concrete answer to guarantee success and profit for a firm looking to participate in competitive bidding. Firms must be low cost suppliers if they want to be competitive in international import tenders. The business marketing process of competitive bidding creates an environment of intense competition and low-cost suppliers will always succeed in buyer's auctions. However, if a firm is able to differentiate themselves in such a way that they gain a competitive advantage over rivals, they may be able to form a business relationship with customers and avoid the competitive bidding process.

6.7. Contributions to Literature

A majority of competitive bidding literature uses previous tender data and rival bidding behavior to create a model and generate results. This thesis aims to address situations in which historical tender data is not available nor is the bidding behavior of competitors. This creates more uncertainty for prospective bidders and this study aimed to encapsulate that uncertainty, formulate it into a working model in order to generate results.

Other than the study done by Takano et al. (2014), there has not been any literature written about competitive bidding that includes risk management techniques. Most literature focuses solely on profit maximization and fails to address the importance of uncertainty and the potential impact that it can have on firm profits. The study included an alternative specification of VaR analysis to address and measure the impacts that uncertainty can have on firm profits. This management technique is powerful in the realm of competitive bidding because firms are submitting bids in hopes to gain business of large volume and value. A slight change in price can alter a firm's profit potential greatly, which makes it important to be able to quantify the uncertainty that firms face when participating in international import tenders.

In relation to agriculture, there has not been an abundance of studies performed relating to competitive bidding, especially at an international scale. This study contributes to literature by focusing specifically on international agricultural import tenders and creating a framework which can be used for competitive bidding in that environment. Global trade in agriculture continues to grow and import tenders continue to be a prominent way of conducting business. A study that can be utilized for cost formulation, optimal bid estimation, and risk measurement and management in the agricultural industry proves to be a contributing asset to the literature.

6.8. Limitations

This study is limiting in that it focuses solely on a specific supply chain for a specific commodity. It does not include the impact of other supply chains procuring the same commodity to the same destination. Regarding the use of the primary rail market, this study does not include the prospective impact of velocity on primary rail values due to a lack of data availability. Lastly, this study does not include precise measurement of demurrage penalties at all stages of the supply chain.

6.9. Further Research

There are a few opportunities for further research regarding this topic. First, more analyzation and model creation could be attributed to the measurement of demurrage and congestion costs. Due to the scope of this study, a relatively simple demurrage measurement was put in place to show the overall impact on competitive bidding. Modeling techniques such as that of a queuing model can be introduced and incorporated into competitive bidding to better estimate the impact of demurrage on optimal bids, expected profit, and the probability of winning.

Another opportunity for further research would be to include the impact of various types of grain contracting. This thesis focuses on the use of a fixed/forward contract and does not include the possibility of bidders procuring the commodity via other contract types (basis, hedge-to-arrive, delayed price, etc.).

Lastly, this framework provides the opportunity for further research on competitive bidding of other commodities and/or services. Whether it be oilseeds, corn, wheat, rice, a construction project or any other commodity or service that is traded through competitive bidding, there is opportunity to incorporate that into this study.

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