A STUDY OF NORTH DAKOTA CROP BASIS VOLATILITY: A MIXED MODEL APPROACH TO TEMPORALLY AND SPATIALLY ANALYZE UNOBSERVED BASIS DETERMINANTS

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ABSTRACT

A model of local elevator basis levels was developed to quantify the response of corn, soybean and hard red spring wheat basis to a set of predefined predictors. Basis data from 2013 – 2016 for 12 grain elevators in Eastern North Dakota were collected. A maximum likelihood mixed effect model was used to test the significance of alternative predictor variables and further divided the residuals into temporal and spatial components. The results indicate that the base model was able to explain 57 to 87 percent of the local basis variability for the selected crops at the individual elevators. In addition, the findings suggest that the temporal portion of the remaining variability is greater than the spatial variability for corn and soybean, but similar for hard red spring wheat.

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CHAPTER 1. INTRODUCTION

World agricultural commodity markets have been flourishing over the past few decades as demand for agricultural commodities continues to increase. An understanding of how these markets fluctuates and interact is therefore important. This paper is aimed at developing an economic understanding and operations of spot and futures markets to explain basis behavior.

There are two broad types of grain markets in the United States- futures markets and spot markets. Uniform contracts for futures delivery are traded at futures market exchanges. For example, a March corn contract traded at the Chicago Board of Trade (CBOT) specifies the delivery of 5000 bushel of number 2 yellow corn to an approved elevator by the second business day after the last trading day in March. These commodity contracts address all the necessary information required for setting the price of the derivatives.

Futures markets are viewed as leading economic indicators because these public markets are the first place to represent expected shifts in supply and demand. The classic example of the sensitivity of futures markets towards supply and demand shifts is the 2008 financial crisis when futures price of crude oil dropped from $145 per barrel in July 2008 to $30 per barrel in December 2008.

In grain merchandising, grain quotes are frequently made in terms of basis. Basis is the difference between the cash price at a specific location and the futures price for a commodity of a similar grade in a specific delivery location (Tomek 1997). Basis is widely used in grain trading rather than price quotes because market participants (elevators, shippers, processors and feeders) can more readily predict how the basis will change overtime, compared to trying to predict absolute price levels. Understanding basis and basis patterns is crucial for any decision that involves the use of futures markets as a tool for price risk management.

Basis, under normal market condition reflects the relative scarcity of commodities, so basis variability reflects differences in this scarcity. Arbitrage opportunities are created due to prices differences across locations, where traders buy from low-price markets and sell to high priced markets. This reduces scarcity in high priced markets and increases scarcity in a low priced markets, which reduces the price in the former and increases price in the later. However, it is important to differentiate between basis variation across different locations (spatial variation) and basis variation over time (temporal variation). Although the arbitrage process is similar in both cases, the causes of variation differs. Hence, the aim of this paper is to determine relative importance of temporal and spatial basis variability.

Basis volatility analysis in this paper will focus on the transmission of changes in basis across interconnected markets. In the United States, some states are net exporters of agricultural commodities and some are net importers. For instance, North Dakota is an important producer of soybean and corn and Kansas, which has a growing livestock industry is a prominent consumer of these crops. It can be inferred that these two markets are spatially linked by the transport of soybean and corn. Spatial basis volatility depends on spatial arbitrage opportunity. Rashid and Minot (2009) states that in competitive markets, spatial arbitrage has the following implications:

- In the long run, spatial arbitrage ensures that price differences between two markets is not greater than the cost of transferring commodities between markets (shipping cost including a profit). If the price difference is greater than the shipping cost, then sellers will buy from the low-price market and sell to the high price market which will reduce the price difference.

- A continuous flow of commodity between two locations implies that the price difference is equal to the shipping cost. To keep this flow live, this price difference has to be large enough to cover all the cost of trading.
- Another implication of spatial arbitrage is that, if the price difference between locations is less than shipping cost, then there will be no private trade of the commodity between locations, because under this circumstance, trade is not profitable. For instance, setting up pan-territorial prices by a government or subsidizing shipment of commodities from surplus regions to deficit regions will force private sector to withdraw from trade.

Arbitrage opportunities results in spatial market integration, where the price of a commodity in spatially separated markets move together, provided that information regarding price is transmitted freely across the market. As stated earlier, with the smooth transmission of information across markets, variability in prices of a commodity in the two spatially separated markets would be less than or equal to the shipping cost between them. Therefore, based on the relationship between the prices of spatially separated markets we can measure the performance of those markets. Accounting for these spatial linkages can be important for developing a specification that appropriately represents basis volatility in economically connected markets.

Markets can be not only interconnected through transfer and processing costs but also it can be connected through time and storage costs. Production and consumption are most commonly carried on at points widely separated in space but it can also be separated in time, and perhaps by relatively long periods of time (Bressler & King 1970). Temporal variation in commodity prices depends on how extensively the commodity is traded internationally or regionally.

The arbitrage opportunity attached to temporally interconnected markets demands storing the commodity when the price is low and selling the commodity when the price is higher. Minot (2009) points out the following implications of temporal arbitrage -

- Temporal arbitrage ensures that the upward movement of prices between two separate time periods will be no greater than the full cost of storage (including profit and risk compensation). If the price increase is temporally greater than the cost of storage, then traders will be induced to buy and store more of that commodity, which will rise the current price (when there is less scarcity) and will lower the future price when there is scarcity. This process will reduce price variability over time.
- Another implication of temporal arbitrage is that the expected price rise will be approximately equal to the storage cost if the commodity is stored between two time periods. Hence, the monthly price increase must be greater than the monthly storage cost to induce traders to store.

The most common phenomena associated with temporal arbitrage is the risk of hoarding-storing commodities with the goal of making excessive profit. But it can be socially beneficial as well. When commodities are plentiful and cheap in the harvesting seasons and expensive and scare in the off-seasons, it is desirable to store commodities and sell onto the market later. Similarly, if the next production cycle is anticipated to be poor, it is beneficial to store/hold some stocks in the bumper production time. Both actions will minimize the price variability through redistributing commodities from a lower scarcity period to a higher scarcity period.

One important difference between spatial and temporal arbitrage is there direction. For example, if there are two markets and two different time periods, spatial arbitrage can take place in both markets, while transfer of commodity through storage can bridge between present and future demand not the vice versa. Another crucial difference is the underlying motivation for spatial versus temporal arbitrage. The actual price difference between two markets is the primary motivation behind spatial arbitrage. On the other hand, temporal arbitrage is motivated by expected price increase between two time periods. This makes temporal arbitrage more risky than spatial arbitrage. That is why the expected risk premium for temporal arbitrage is higher, compared to spatial arbitrage.

Storage decisions are made based on expected future prices. Thus, expected future actions can affect current prices. For instance, based on the anticipation that the next harvesting season will be a poor one, traders will be induced to store more of a commodity. This will increase the spot price because more traders will enter the market to buy the commodity. On the other hand, release of the stored commodity into the market in the period of scarcity will lessen the price hike in lower production period.

In a competitive market where there is enough information regarding the price movements, the mechanism of redistributing commodity from a low priced market to a high priced market and from low priced period to high priced period will work well. This will reduce both spatial and temporal variability. However, it is not expected that markets will eliminate all price variation over time. This is because the removal of price variability will exceed the social benefits by destroying arbitrage opportunities.

There has been substantial research effort to explain factors affecting basis and forecast basis levels. However, no known attempt has been made to model basis volatility spatiotemporally. This research uses a maximum likelihood based mixed model approach to quantify the volatility structure of North Dakota’s corn, soybean and hard red spring wheat basis in temporally and spatially separated locations. This study seeks to understand the heterogeneity in local basis behavior in response to a set of predefined predictors. More specifically, the main objective of this research is to calculate the proportion of the total variance in North Dakota’s corn, soybean and hard red spring wheat basis that is accounted for by time and elevator locations. Remaining sections are as follows: a broad discussion on related literature; an outline of the data and specification of the model; analysis of the findings and finally, a concluding discussion on the findings of the research.

CHAPTER 2. LITERATURE REVIEW

Agricultural commodity price volatility is not a new concern. This issue has been questioned by academics, policymakers and food supply chain stakeholders because of its importance to clearly understand market and financial risks. But analyzing agricultural commodity price volatility is difficult compared to with that of stocks and bonds because of stylized facts like seasonal supply and demand, weather conditions and storage and transportation costs (Symeonidis et al. 2012). This section will provide a detailed overview of the literature on agricultural commodity price volatility and its patterns. The literature discussed here focuses on theoretical and empirical aspects of price volatility, interaction between spot and futures markets, price information in futures markets, temporal and spatial aspects of volatility and macroeconomic implications of price volatility.

2.1. Market and Price Structure of Agricultural Commodities

Today's economy is highly specialized, which increases productivity and living standard. Development of an efficient marketing system is the prime reason behind this specialization and this system binds together activities like transportation, storage and transferring effectively. A detailed discussion on markets in space, form and time is necessary to understand the dynamics of price volatility.

The direct function of any marketing system is to ensure the transfer of and the movement of goods and services from producer to consumer. But price discovery or price formulation is an even more essential role of modern marketing system. Under such an economy, the concurrent flow of resources to alternate uses and the goods and services to consumers are directed by price. Prices here direct producers in choosing enterprises and in purchasing factors of production. Prices also allocate available supplies of goods and services among consumers.

A market or marketing system is primarily concerned with creating time, place and ownership utilities. In a broad sense, a market is the platform for moving physical goods from producers to final consumers. Bressler and King (1970) state that activities that ensure this movement can be classified as concentration, equalization and dispersion. Concentration refers to the assembly of commodities from producers, channeling these commodities to the intermediaries and dispersion is the movement of these commodities from intermediaries to final consumers. Equalization is adjusting the movement of commodities based on supply and demand conditions. Intermediaries can be thought of as a balancing factor because they balance between fluctuating supplies and changing needs and demands of final consumers. In the United States, this process is managed more or less automatically through the marketing system.

Based on these discussions, a market can be defined as an area or setting where producers and consumers communicate with each other. Supply and demand conditions operate to transfer ownership. Under these conditions, prices are established and price movements are responsive to supply and demand forces. If there is a huge supply of a commodity in the market, prices will drop. Hence consumers will be encouraged to buy more and producers will offer less. This will reduce profitability and eventually production pattern will be shifted.

Through this system of interrelated commodity and production factors market, prices become the primary directors of economic activity. Production is influenced when commodity prices interact with input prices. This interaction helps allocating scare resources. Consumption is also influenced because with the increase in input price, price of final products increase too. Thus, input prices are the most important determinants of income and consumption of final consumers.

The price of agricultural commodities varies greatly, from port to port, terminal to terminal and exchange to exchange. This is because production and distribution of agricultural commodities are sensitive not only to general supply and demand conditions but also to commodity characteristics, transfer costs, government policies, input costs, diseases and international market conditions. For example, the grain handling network in the U.S. is very complex. It consists of storage, trucks, barges, railroads and grain elevators. Prices may change at any one of these points as grain marketers constantly search for cost effective ways to transfer the grain from origin to destination.

Market information also influences agricultural commodity prices. Equilibrium between supply and demand of a commodity and associated price levels change as market participants receive new information (Schnepf 2006). Actions in the market by its participants are generating gigantic amount of information. Through sources like private trading tools (Bloomberg, DTN, Thompson Reuters Eikon etc.), Government agencies (United States Department of Agriculture) and Commodity futures exchange (Chicago Board of Trade, Kansas Board of Trade, Minneapolis Grain Exchange etc.) information are readily available to the market participants. Morris and Shin (2002) study welfare effects of public information and state that public information is effective at influencing agents' actions and thus on equilibrium outcomes. However, the pricing transactions that are common in agricultural commodity market has two components. One concerns the market price that is discovered on the commodity exchange, and can be referred as price level or current price. It depends mostly on current demand and supply situations. The other concerns the difference between a cash market price and a selected futures contract price or expected price. These issues are broadly discussed next.

2.2. Current and Expected Price

To better analyze demand and supply of agricultural commodities we need to understand the difference between current and expected prices. Expected prices are particularly important for understanding demand for storage and speculation. But identifying demand for storage and speculation is not easy because of the level of expectation of the various participants of the market. On the other hand, current prices are important for analyzing immediate consumption and export. Storage locations (on-farm and commercial) will influence current and expected price. On-farm storage involves both fixed and variable costs[1] and this type of facility needs significant investment in bin along with costs like site selection costs, wiring, fans, concrete, transfer legs and augers. Commercial storage involves variable costs such as electricity to operate fans, insecticides and fungicides, fuel to operate augers, and the operator's time for handling the grain in and out of the bin as well as monitoring grain condition. It also involves fixed investment cost, which is usually higher than that of an on-farm storage. But these investments can be spread over the life of the facility more economically, since crop turnover ratio (the number of times the crop is replaced during a given period of time) is higher in commercial storage. Thus, based on the storage decisions, pricing will be different. After storage decisions, one of the major challenges is to incorporate price expectations in the demand equation.

Ferris (1998) states that one approach (for commodities traded on the futures market) to do this, is to presume that storage operators expect cash prices to be equal to some futures contract less normal basis with respect to the cash market. It will not be an exaggeration if we say that storage operators' gross margin depends on how effective they are in using futures market with respect to cash market to hedge their positions. If gross margin expectation is high, then the storer will demand more. Ferris (1998) also states that if the total amount available is fixed or perfectly inelastic (as is typical in the short run) the storers' bid the product away from

[1] see https://www.extension.iastate.edu/agdm/crops/html/a2-35.html

consumers or exporters, which, in turn, tends to drive up the current price and reduce the expected gross margin. Thus, demand by storers' and speculators for agricultural commodity is an important source of volatility in commodity markets. This is particularly true in short run variability in prices when no discernible change in demands from domestic or foreign consumers is evident. In next chapter, issues concerning supply and demand has been discussed elaborately.

2.3. Aggregate Supply and Demand

Both demand side (population, level of economic development, changes in consumption etc.) and supply side (available arable land, weather, prices of factors of production etc.) factors play a key role in shaping agricultural commodity prices. Forces of supply and demand in agricultural commodity market are in a constant state of flux. If supply and demand were both certain, prices could be adjusted without an organized market. But, supply and demand of agricultural commodities are large and both are uncertain and subject to wide fluctuations from year to year and season to season. Borychowski & Czyżewski (2015) states that adverse global changes of supply-demand relations (affected by changes in both supply-side and demand-side factors) influenced the record increase of agricultural commodity prices after 2006. From a general macroeconomic perspective, the volatility in agricultural commodity price can be influenced by supply inelasticity and price inelasticity of demand in short run.

Rhodes (1978) states that the aggregate demand curve for an individual farm commodity at the farm is likely to be inelastic. He further states that a farm facing an inelastic demand would rise its price because doing so would increase total revenues while decreasing output and thus reducing its total costs. Typically, a farmer engages himself in production without knowing what price level will be realized. The individual farmer, however, is price taker as he reacts with output changes that are rational in terms of expected prices. Thus, farm production can be leveled as schedule of amounts that farmers produce or willing to produce at different expected price levels. Holding other things constant, this assertion is parallel to the demand definition where prices are related to the purchases. While demand theory holds that consumer purchases are inversely related to price, supply theory strongly proposes that production or amounts supplied to the market is directly related to price. Profit maximization is the focus.

Planting decisions for major crops such as corn and soybeans are made in the spring as much as seven months ahead of fall harvest. These biological lags in agricultural production heavily influences farm profit. This causes farmers to make decisions based on expected price rather than realized prices. The realized price will be affected by the time scale, the size of the crop and possible shifts in demand during the production period. The size of a crop can frequently vary because of weather and other factors beyond the effective control of farmers. Moreover, at the time of planting decision, a farmer doesn't know the intended size of the crop.

Because of the role of expectations and lagged response to those expectations, the time frame being considered is particularly important in supply analysis. This is true to a much lesser extent in demand analysis. In the short run (less than one production period) supply is perfectly inelastic; this is the change in price expectations that will not affect the amount available. For that reason, supply analysis incorporates a minimum time frame of one production period. The complexity of how expectations are formulated and the importance of asset fixity in agriculture dictate that farmers respond to changing prices beyond one production period. The longer the time frame, the greater the supply elasticity.

Based on the above discussions, one may be tempted to think that biological lags in agricultural production may help expected prices to predominate farm supply scenario. For the United States this is not particularly true. Our agricultural commodity trading is a complex fusion of cash market, futures market and forward contracts market. The interplay of different uncertain economic forces produces the constant price fluctuations which necessities the existence of a futures market.

Prices in the futures market are a measure of the aggregate supply and demand conditions for a commodity. Local prices are not only influenced by local supply and demand but also by aggregate conditions. Thus, basis will always change with the changes in local conditions relative to the changes in aggregate conditions. This issue is discussed broadly in the next section.

2.4. Futures Market

Commodity futures market have three major roles to fulfil- price discovery, risk transfer and investment medium. Exchanges provide the physical facilities and business framework for buyers and sellers to conduct trading. Worldwide demand and supply condition are interpreted by traders. Prices are discovered by the interaction of buyers and sellers. This process involves two types of people- hedgers and speculators. Hedgers seek to transfer the effects of price change from their business, and speculators seek to profit from price change.

The simplest way to reduce the price risks of ownership is called naïve hedging. In general, a naïve hedge is the taking of equal and opposite positions in cash and futures market. Other hedging options are cross hedge (hedging a commodity position by taking an offsetting position in another commodity with similar price movements) and optimal hedge (positions in the cash and futures markets are opposite but not equal). These are the most obvious ways to reduce the price risks of ownership- by reducing the length of time that one is an owner. This possibility is not always as impractical as it may sound. Some farmers sell their growing crops or livestock by contract, weeks or months before those commodities can be marketed, thus reducing the time during which they are subject to ownership risks. Farmers have sizable investments in crops and animals in the process of production (growing crops and animal) that are equally subject to wide swings in prices. Hence, some farmers seek to minimize their susceptibility to such price risks through hedging. So, farms (as hedgers) must minimize these swings in value because they lack the financial capability to withstand large losses in value. A local elevator may expect to earn less per bushel for receiving and shipping wheat than the possible daily fluctuation in the market value of that wheat.

Futures markets are speculative in nature which offer the possibility of gaining arbitrage revenues. Efficient future markets can incorporate new information into prices. These markets allow for the transfer of risk from commercial traders, who are exposed to futures price movements, to non-commercial traders, who are frequently labeled as speculators and take short (long) futures positions in the hope of yielding a capital gain from the fall (rise) in prices. Beckmann and Czudaj (2014) analyzed spillover effects between various futures markets for agricultural commodity. Spillover effect is important for several reasons as it reveals general causality patterns and co-movement of various futures market that is crucial for both investors and policymakers. In an early study, Buguk et al. (2003) examined the price volatility spillover in U.S. catfish markets and concluded that a strong volatility spillover from feeding material to catfish prices can be observed. More recently, Von Ledebur et al. (2009) analyzed whether and to what extent the volatility of agricultural commodity prices at different market places were transferred during the dramatic price changes of 2008.

2.5. Agricultural Commodity Price Volatility

According to the policy report 2011 of International Fund for Agricultural Development, most agricultural commodity markets are highly volatile because of periodic variability in agricultural output, demand inelasticity and supply inelasticity in short run and longer production time. In a purely descriptive sense volatility refers to variations in economic variables over time.

At times the prices of many commodities display volatile behaviors. Since agricultural commodities are among the fundamental inputs of our economies on the production and/or consumption side, price volatility causes disruptions and can lead to crises. Both cash and futures prices contain important information regarding variability. Futures prices facilitate forward contracting which is very important for seasonal market operations. Elevators (at local and export facilities) hedge grain prices and set their cash offers based on the futures prices. Thus, both the cash and futures prices are highly correlated.

An improved understanding of price behavior is therefore highly desirable from a policy as well as from a consumer and supplier perspective. There is considerable amount of literature on agricultural price volatility and possible causes that have impact on it. Anderson (1985) reported that seasonality is a main factor that affect variability of agricultural commodity prices. Kenyon et al. (1987) also reported the similar findings. Goodwin and Schnepf (2000) examined corn and wheat and Chatrath et al. (2002) examined soybeans, corn, wheat, and cotton futures prices. All of them reported statistical significance of seasonality effect on futures prices.

Gilbert (2010) analyses, global factors like exchange rate, investment in future market monetary expansion have influence on price volatility. William and Wright (1991) suggest that market specific shocks such as weather shocks, bio fuel mandate have also a part in price volatility. Because of the enormity of this issue there is no generalized model that can properly visualize price volatility in a given market or of a commodity. However, Gustafson (1958) suggests a model that incorporates behavior of grain market prices and identify the causes of high volatility as it is crucial to understand the relation between prices and stocks.

Some of the previous studies used single time series of futures price to analyze volatility. Yang and Brorsen (1993) used continuous price series to study seasonality and maturity effects in several futures markets. In the similar fashion, Khoury and Yourougou (1993) studied futures price volatility at Winnipeg commodity Exchange and found that year, monthly, contract month, maturity and trading session affect volatility of barley, canola, feed wheat, oats, flaxseed and rye.

Use of single delivery month contract and roll it over till maturity is another approach of analyzing price volatility. Kenyon et al. (1987) used rolled over March soybeans, March corn and July wheat contract to estimate the determinants of price volatility in these temporal markets. In another study, Streeter and Tomek (1992) investigated seasonality in price volatility using rolled over March and November soybeans contracts. One important finding of their study is the nonlinear effect of time to delivery on price volatility. They used Seemingly Unrelated Regression (SUR) technique to model March and November contracts. Hennessy and Wahl (1996) analyzed several delivery months separately. Their findings show that for Kansas wheat, Chicago wheat, soybeans, corn and Minneapolis wheat price volatility, seasonal effect is significant but time to delivery and inventory effects are not. Goodwin and Schnepf (2000) studied endogenous factors of price risks. They used December corn and September wheat contracts to estimate the significance of inventories, trading volume, seasonality and growing conditions on price volatility. Their findings on seasonality supports the study by Hennessy and Wahl (1996).

Constructing separate time series of the futures prices by the delivery zone is another approach used by previous researchers. Mann and Dowen (1996) studied the effects of USDA hogs and pigs' reports on the nearby and distant live hog futures contracts. Schaefer, Myers, and Koontz (2004) estimated the efficiency of live cattle futures contracts by analyzing first deferred and second deferred live cattle futures contracts. Kalev and Duong (2008) used a more efficient approach. They applied SUR framework in five different time series constructed by rolling over the first closet through the fifth closest maturity contracts.

GARCH specifications have been used extensively to model agricultural commodity futures prices. Manfredo, Leuthold, and Irwin (2001) evaluated integrated specifications method, GARCH Model and implied volatility from options method to estimate futures price volatility for fed cattle and feeder cattle. Their result suggests that integrated specification provide most accurate forecasting when implied volatility and time series data are available. Ramirez and Fadiga (2003) used an asymmetric-error GARCH model to forecast soybeans, sorghum and wheat futures price. Crain and Lee (1996) estimated the effect of farm programs on wheat spot and futures price volatilities. Their result suggests that voluntary farm programs have increased volatility of wheat prices. On the other hand, mandatory farm programs actually lowered volatility. In another study, Yang, Haigh, and Leatham (2001) used various types of GARCH model to estimate futures price volatility of corn, soybeans, oats and cotton. However, this study took a different approach. Most of the previous studies were aimed at forecasting price levels. But this study contributes to basis literature by examining the spatiotemporal movement of basis volatility. It does so by analyzing volatility determinants across delivery horizons during a pre-specified time period using a maximum likelihood based mixed effect model that estimates both regression coefficient and variance components.

2.6. Basis and Related Studies

There is significant amount of scholarly works on basis of agricultural commodity. Some earlier scholars like Working (1949) viewed commodity basis as intertemporal price relationship which is the price differential between cash and futures market. Weymar (1966) in his intertemporal pricing model, states that price difference between cash and futures market is a function of expected inventory behavior. Jiang and Hanyenga (1997) states that basis involves two price relationships- delivery point cash and futures price relationship and local and the delivery point cash prices relationships. First one can be denoted as temporal price difference. According to theory of storage (will be discussed in later section) temporal price differentials should be equal to storage return or price of storage. The later represents spatial price difference, which should be equal to transportation cost between two locations. Thus, basis can be viewed as the sum of transportation cost and storage return.

Both the supply and demand for storage determine the price of storage. Tomek (1997) viewed price of storage as a function of opportunity cost, direct storage cost and convenience yield (expressed as supply of storage equation) and inventory as a function relative demand for consumption over two periods, production and the price of storage (expressed as demand for storage equation). A more abridged version of the price of storage model, derived from these two equations, shows that price for storage is a function of opportunity cost, direct storage cost, demand in two periods, production and yield. Furthermore, transportation cost, basis and sum of these two (transportation cost and basis) are influenced by storage and transportation costs, production and stocks and local economic conditions (local grain consumption, limitations of storage and transportation capacity)

2.7. Theory of Storage

Storage creates time utility. The objective of storage is to make goods available at the desired time. Some storage is unavoidable in the sense that all agricultural commodities must be stored even as they are being transported, processed and made available to retail shoppers. However, any movement through a long channel can seldom be a continuously even flow.

Therefore, there must be reservoirs along the line that allow for uneven flows. Reservoirs are obviously most essential for annual crops.

Some earlier literatures by Gustafson (1958), Samuelson (1971), Scheinkman and Schechtman (1983) focused on competitive storage model which views stocks as a key determinant of commodity price behavior. The corn, soybean and hard red spring wheat basis model formulated for research to capture basis volatility is also based on the hypothesis that if current price is lower than the expectation, economic agents will use storage as an option to sell the commodity in future date in the expected price level. This scenario will flip if the prices start declining as there will be no incentives to store and stock-out case will be predominant.

Another way to explain commodity pricing is through theory of storage. This theory explains commodity price behavior based on economic fundamental. Significant amount of works has been done using this theory to explain price volatility. For example, Fama and French (1988) studied the effect of inventory on commodity prices and their volatilities. Symeonidis et al. (2012) used real inventory data on 21 commodities to analyze the relationship between inventory and futures prices. Theory of storage can also be used to analyze basis. One important linkage between cash and futures prices, is the costs associated with the storage. This helps us to understand why as storage season progresses, cash prices increase relative to the futures prices. It is expected that during the delivery month, prices should be equal at delivery locations as both contracts (cash and futures) become identical commodities. But basis may not always be zero due to uncertainties in supply and demand.

Storage theory suggests that cash price of a commodity should be below the futures contract by the cost of carrying the commodity from harvest to that specific contract month. Not only that, but the difference between the cash and futures prices (basis) should also accommodate transportation costs for geographically dispersed markets. While studying the corn basis of Illinois, Garcia and Good (1983) argued that basis movement is generally consistent with the theory of storage and cost of transportation. But in many occasions, storage cost may not be the exact difference between futures contracts prices at different delivery dates. This may happen because of the risk associated with storage. Common characteristics embedded with storage risk include bottlenecks, safety stocks, and the bullwhip effect (Wilson and Dahl, 2000). Grain industry bottlenecks occur in facilities which handle high volumes of grain in short time periods (Wilson, Carlson & Dahl, 1998). Safety stocks or inventories held at various points in the supply chain are a strategy to offset the large numbers of uncertainties in the grain supply chain. The bullwhip effect is a distortion in ordering as the supply chain moves further from the customer (Billington & Lee 1992). Another way to view this anomaly is to study the factors other than storage and transportation costs that may influence basis and can cause inverted market situation (e.g. cash price above futures price). Kaldor (1939) studied the extent to which the spread between the price for immediate delivery and the nearest conceivable futures price falls below full carrying charges. Tomek and Robinson (1972) states that both the supply and demand for storage affect equilibrium level of price of storage and the size of the inventory. They also include that flow of information, inventory use rate, quality deterioration rate of inventory may also affect the basis (which they termed as price of storage). Supply and demand of storage is mainly determined by size of the stocks, the rate at which commodities flow to the market and demand for shipment (Garcia & Good 1983).

2.8. Basis Volatility Studies

Without proper understanding of the concept of basis and basis volatility it is very hard to fully comprehend agricultural marketing and market strategy (Tomek 1997; Hauser, Garcia, and

Tumblin 1990). There are very few studies which focuses on basis volatility compared to the analysis of price volatility (both futures and spot price) of agricultural commodities. One reason of this scarcity is lesser availability of local cash price data, which are the integral part for determining basis time series. However, there are some studies which endeavored to explain factors that significantly affect basis. For example, Davis and Hill (1974) found that spatial price differentials among Illinois country elevators are significantly influenced by seasonal adjustments, local demand and supply conditions and availability of transportation facilities. Garcia and Good (1983) have examined basis relationship for corn in Illinois and found that basis pattern is influenced by stock, cost and flow factors. Kahl and Curtis (1986) measured the empirical significance of supply and demand factors in grain basis determination. Jiang and Hanyenga (1997) found that there is seasonal pattern in basis volatility and relative importance of variables such as storage cost, barge rates, local demand affecting basis variation varies seasonally. Based on these findings it can be inferred that, storage capacity, transportation cost and competition are some of the most important factors that influence basis.

Furthermore, some of the previous studies also examined basis forecasting methods. Hauser, Garcia and Tumbin (1990) used historical averages of basis to predict soybean basis. Dhuyvetter and Kastens (1998) compared various forecasting methods of basis for wheat, corn, milo (grain sorghum) and soybeans in Kansas and found that there is seasonal variation in basis forecasting for all crops and these variations are high at critical production time periods. Taylor, Dhuyvetter, and Kastens (2006) compared practical methods of forecasting basis using current market information (basis deviation from historical average) for wheat, soybeans, corn, and milo (grain sorghum) in Kansas provides more accurate post-harvest basis forecasts. Although there is extensive amount of research in basis forecasting but there are very few studies which focused on modeling the agricultural basis in terms of temporal and spatial dimensions. However, there are multiple researches on volatility analysis of futures prices of various agricultural commodities. There is a close relationship between basis and futures prices. That is why it is important to review these literatures to examine the factors that are important to temporally and spatially analyze the basis volatility. Some of the previous studies indicated that basis of spatially separated markets is linked. McKenzie (2005) found that with an increase in the transportation cost (barge rate) basis level react negatively, and shocks to the Gulf basis level are transmitted to farm level (Little rock and Memphis Market). Shocks at the two interior markets do not affect the gulf basis, which indicates spatial relationship. Manfredo and Sanders (2006) used bi-variate Granger Casualty tests to investigate the relationships of corn basis at different market locations. Their finding suggests that corn basis calculated at the export terminal markets of Toledo and the U.S. Gulf, as well as the Illinois River plays a key role in determining the basis for other river terminal and interior locations. Lewis et al. (Lewis, et al. 2010) also used the similar method to find out the causal relationship between thirteen (13) corn markets. They determined the average spillover effect by developing a spatial autoregressive model and found that basis is simultaneously determined in these markets.

2.9. Transportation

Almost all agricultural commodities acquire place and time utility by transportation from producers to intermediaries and then to consumers. The demand for transportation varies with the size and location of harvest. Truck and rail transport cost are significant. The transport share of marketing costs varies greatly by product. The bulkier and lower valued the commodity, the more important are transport costs as a limit on the extent of the market. For agricultural commodity pricing, transportation is even more important. Problems need to be addressed with regard to transportation are- to what extent transportation cost affect prices, and how these effects are related to geographic locations. In some earlier works transport cost has not only been used as a variable for forecasting the change in basis but also to explain the basis. US rail rate index was used by Kahl and Curtis (1986) to explain the import cost of grain to South Carolina. To study grain exporting through the river system, Jiang and Hayenga (1997) used St. Louis barge rate to study the effect on corn and soybean basis. Wilson and Dhal (2010) used rail rate data and ocean rate spreads to explain variability in origin basis values. Several USDA studied reported that rail transportation costs represent a significant percentage of the average on farm commodity price. Study of rural transportation issues published by USDA, AMS reports that average rail tariff rates as a percent of the farm price of wheat have varied from 11.3 percent in 2007 to 23.1 percent in 1999[2]. Another study by USDA reveals that rail transportation costs for individual movements of agricultural products have been as much as 40 percent of the delivered price. In a study, O'Neil Commodity Consulting analyzed the relationship between origin basis, destination basis and transportation costs by examining thirty-six (36) soybean loading facilities across seven states (Illinois, Indiana, Iowa, Nebraska, North Dakota, Ohio, and South Dakota). The study concluded that increased transportation costs have had a negative impact on the interior basis.

2.10. Macroeconomic Implication of Price Volatility

A certain degree of volatility is accepted and desirable because with volatility markets would become stall. Price volatility is an important part of market and notably it is not consistent across the commodity markets. Stakeholders of agricultural commodity markets are finding commodity prices to be volatile. But compared to energy market, this volatility is still low.

[2] See U.S. Department of Agriculture, Agricultural Marketing Service. (2010). Study of Rural Transportation Issue. https://www.ams.usda.gov/services/transportation-analysis/rti

Energy market volatility has significant impact on agricultural commodity price volatility. Rosa and Vasciaveo (2012) found that there is an exogenous influence of the oil price on the US agricultural commodity markets. Nissanke (2012) studied price dynamics in both agricultural and oil futures market. Based on the conditions like structural changes in market fundamentals and interactivity between commodity and financial markets, she reported that recent price volatility is common across commodities. Babcock (2012) reported that volatility in US agricultural market has actually increased because of biofuel policies. Volatility is common in other markets too such as metals, which has experienced a higher volatility than energy markets.

One important policy implication of volatility is its impact on balance of payment. In macroeconomic terms, export oriented countries benefit from price hikes because it improves their balance of payments conditions. On the other hand, import based countries experience decreasing current account balance. Another important issue is food security. Tothova (2011) states that volatile variable price has direct link with food security as high prices effect the ability of the consumers to buy food. Although intermediaries and producers become benefitted from such situations. In the absence of proper risk management tools producers and processors are the most vulnerable parties who get exposed to the uncertainty associated with price levels. High swings in prices make processors unable to secure supplies and control input costs. Volatility in input prices (fertilizer, oil etc.), as stated earlier, affects both the agricultural production and decision making.

CHAPTER 3. DATA

A detailed dataset has been developed to analyze basis volatility. Data used in this research were collected from a variety of secondary sources. Corn, soybean and hard red spring wheat (HRSW) basis quoted by local elevators and export terminal markets (destination bases) from January 2013 to December 2016 were analyzed. Futures market contract delivery months for corn and HRSW are March, May, July, September, and December and delivery months for soybean are January, March, May, July, August, September and November. Local basis levels and futures market prices are quoted in cents per bushel.

The two most important destination for the grains shipped from North Dakota country elevators are- Pacific North West (PNW) and Gulf of Mexico (GOM). PNW includes the states of Oregon, Washington and Idaho. These destinations consist primarily of Columbia River and Seattle-Tacoma export elevators. GOM includes Galveston, Texas and New Orleans, Louisiana. For PNW, weekly basis in Oregon and for GOM, weekly basis in Louisiana (Thursday position) were considered. Minneapolis Grain Exchange (MGEX) is the primary futures market for trading Hard Red Spring Wheat. Thus, MGEX 20 day to arrive truck bids quoted by terminal elevators at Minneapolis, MN location has been used.

Inland basis quotes or local basis levels (basis quoted by local elevators) and export terminal market (destination bases) quotes for corn and soybean were obtained from three major databases- Bloomberg, Thompson Reuters Eikon and DTN ProphetX. Minneapolis 20 day-to-arrive truck bids and PNW (Portland, Oregon) 30 day-to-arrive rail bids for HRSW were collected from USDA, Agricultural Marketing Service. Nearby futures price (quoted by Chicago Board of Trade and Minneapolis Grain Exchange) were also collected from USDA, Agricultural Marketing Service.

According a report[3] by United States Department of Agricultural, most of the grain and oilseed shippers in North Dakota are dependent on rail transport because of the distance to inland waterways from shipping points and the prohibitive cost of hauling grain long distances to markets by truck and limited local demand. This report also states that, during the crop marketing years 2009 to 2012, on average rail road transported 80 percent of North Dakota grain and oilseeds. Therefore, this research considered rail as the primary mode of grain shipment originating from North Dakota.

Supply of railcars are allocated among shippers through an auction bidding process. In the United States, there are two types of railcar auction markets- primary market and secondary market. In the primary market, rail service contracts (these contracts are for a one year duration) are originally sold by railroads to shippers. Sales in this market are administered by railroads. Auctions in the primary market are guaranteed for delivery within a specific time frame. Shippers often bid an additional premium over the base, or tariff rate, for the guaranteed use of the grain cars. The bidding process determines how much this premium will be. During a period when there is high demand (low supply) for railcars, bids will above the tariff rate. During a period of low demand (high supply) for rail cars, bids will be at the tariff rate or will go unsold. In this research, only published tariff rates with fuel surcharges ($/per bushel) will be considered.

Shipper may buy or sell services purchased in the primary market to other shippers in the secondary market. Buying or selling of rail service contracts in the secondary market depends on how supply and demand for railcar changes for the specified delivery period.

[3] See Rail Service Challenges in the Upper Midwest: Implications for Agricultural Sectors – Preliminary Analysis of the 2013 – 2014 Situation.
https://www.usda.gov/oce/economics/papers/Rail_Service_Challenges_in_the_Upper_Midwest.pdf

Bids of secondary market may either sell for more or less than the original primary market price. In the primary market, railroads are the sellers and they offer services in this market is on a take-it-or-leave-it basis. Thus, railroads have no incentive to offer guaranteed service below $0 in the primary market. But the shipper who has purchased a guaranteed service in the primary market, for an entire year, can be a seller in the secondary market, for a specific delivery period. Thus, if the rail service is no longer needed by the shipper, they may resell the contract to another shipper in the secondary market at a premium (if railcar demand is high and supply is low) or at a discount (demand is low and supply is high). That is why negative bids are not uncommon in the secondary rail service market, for a specific delivery period. Negative bids are the amount that is discounted from the underlying tariff rate. Like railroads, shippers also have no incentive to sell their purchased rail services at a discount that exceeds their total cost of defaulting on the shipment.

Weekly market changes and unexpected events, such as weather, transportation disruptions, revised grain production or export sales data, and exchange rates are highly likely to distort optimal supply and demand arrangement reflected by primary market bids. Often, secondary rail service markets approximate these distortions justifiably. Therefore, to capture these risk elements secondary market auctions of shuttle and non-shuttle rail service are used. Two time periods were considered for secondary market bids- nearby bids (T_0) and bids auctioned in the previous month for scheduled delivery in next month (T_1). For example, a March bid of $200 per car for a shuttle train delivered in March would be T_0. While a February bid of $100 per car for a shuttle train delivered in March would be T_1. Both the primary and secondary market bids were collected from Grain Transport Report (GTR) dataset compiled by USDA, AMS.

Weekly export sales for corn, soybean and spring wheat were obtained from USDA, Foreign Agricultural Service. Futures market spread (futures carry) is calculated manually.

The model used to estimate local elevator basis levels in this study can be grouped into four categories of predictors; seasonality, out-of-state demand, transport cost and storage cost. A detailed explanation of all the categories used in this research are given below.

3.1. Basis: Local and Terminal Market Quotes

Historical basis values (measured in cents per bushel) for twelve elevators from Southeast and Northeast North Dakota were collected for this study. Elevators from both regions were chosen for a set of reasons. Crop concentration is the first reason. Northeast ND has a heavy concentration of HRSW production whereas corn and soybean are predominant in Southeast ND (Figure 1). Categorizing elevators based on the crop concentration will determine how supply levels contribute to local basis volatility. Elevators were also chosen because of their proximity to either in main rail line for BNSF or the main branch lines (Figure 2). Third reason was the delivery point vicinity. One of the main hypothesis of this research is that strong local demand helps stabilizing the basis volatility. Regions chosen for this study differs in their proximity to the local processing facilities. The Southeast region is the delivery point for three ethanol processing plants and one corn sweetener processing plant. On the contrast, Northeast ND has no local demand bases for corn. Elevators of the Northeast region are far enough away from these processing plants that truck delivery is not economical under normal market conditions. Thus, basis mechanism for corn will differ because of the intensity of local demand (i.e. elevators in the Northeast ND indirectly compete with ethanol industry and milling plants whereas as Southeast ND elevators have direct confrontation with these processors).

On the other hand, Northeast ND is close to the North Dakota State Mill and Elevator, which is a large wheat milling facility. Proximity of the wheat milling plant may affect basis quoted by Northeastern elevators as farmers of this region has the option to deliver their grain directly to the milling facility. Hence, local basis is expected to reflect the diversity in local supply and demand conditions.

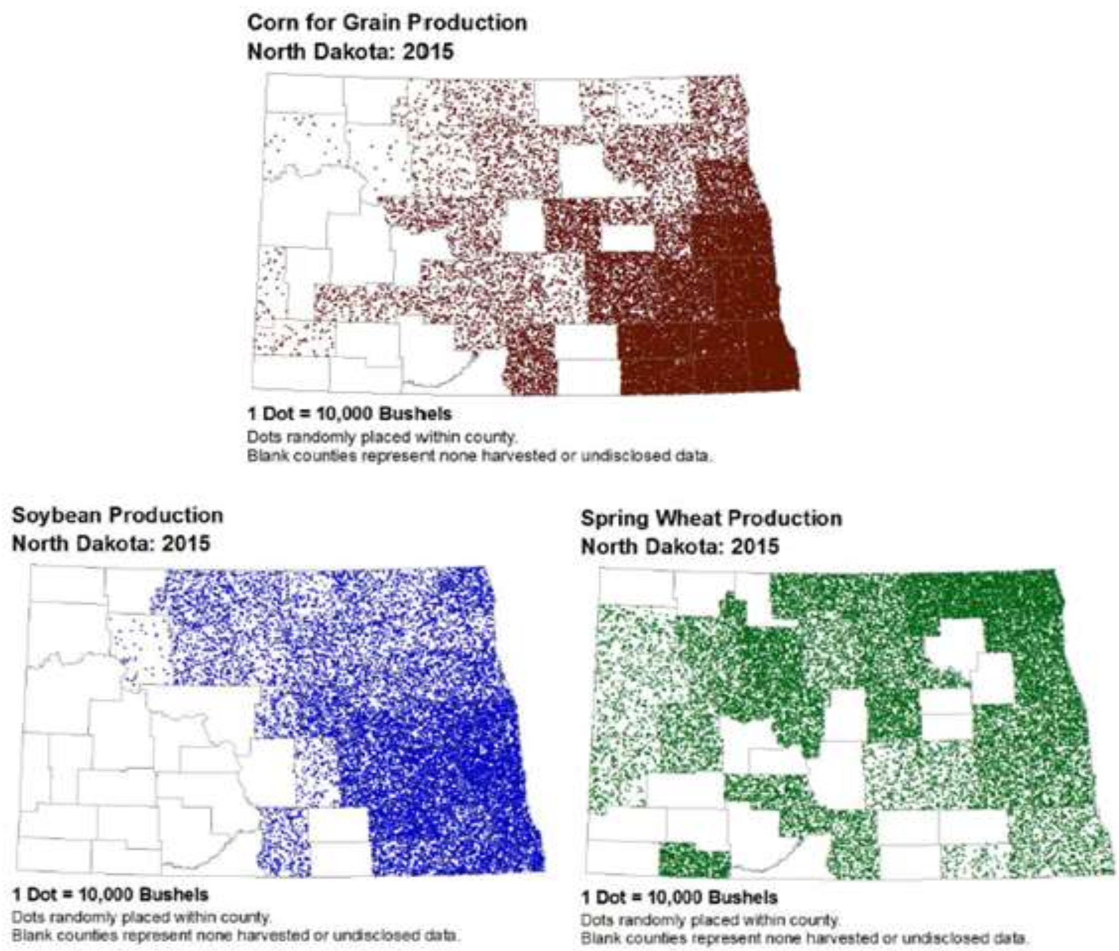

Figure 1. North Dakota Grain Production Map 2015

Table 1 lists the twelve elevators and their locations. To better capture the price variability, instead of averaging the weekly basis quotes (both local and export terminal basis), Thursday nearby basis levels for all three commodities were used. In cases where a

Thursday quote was not available, the corresponding Friday quote or the immediate following Monday quote was used. Local basis data were collected from Bloomberg and Thompson Reuters.

Table 1

ND Elevator List

District	Elevator Name	Location
Southeast North Dakota	Arthur Companies	Ayr
	Alton Grain Terminal	Hillsboro
	Central City Grain	Carrington
	Finley Farmers	Finley
	Dakota Ag. Cooperatives	Kindred
	Full Circle Ag.	Forman
Northeast North Dakota	BTR	Leeds
	Thompson Farmers	Thompson
	CHS	Drayton
	Equity Farmers Co-op	Sheyenne
	Osnabrock Farmers	Osnabrock
	Northwood Farmers	Northwood

Table 2 and Table 3 provide summary statistics for the basis quotes series of the three commodities in the Southeast and Northeast regions, respectively. Results indicate that the mean basis ranges from -55 cents to -80 cents for corn, -72 cents to -123 cents for soybean and -39 cents to -58 cents for HRSW across all the locations. Standard deviation of soybean noticeable differs across regions'. Soybean's standard deviation ranges from 37 cents to 41 cents for the locations in Southeast region, but for Northeastern elevators this range is 39 cents to 69 cents. This is because the production of soybean is more concentrated in the Southeastern region compared to the Northeastern region.

The weakest basis values were offered by Osnabrock Farmers for corn, by CHS Drayton for soybean and by Arthur Companies for HRSW. Based on this observation one important observation can be made- Northeastern elevators offer the least attractive cash market bids for corn and soybean. Again, crop concentration is playing an important role behind this market structure.

Figure 3, 4, 5, 6, 7 & 8 show the basis movement for corn, soybean and hard red spring wheat. Corn and soybean basis at both regions were noticeably volatile during 2013 and 2014 with some sharp rises and declines. For example, Figure 3, 4, 5 & 6 show that, corn and soybean basis was strong in July 2013 with a subsequent weak period in August 2013 and basis levels for both commodities were fairly stable during the rest 2013. Both the commodities basis levels started weakening from early February 2014 and were weakest in April 2014. 2015 and 2016 was a balanced year for corn and soybean at both regions with no sharp changes at basis levels. Figure 7 & 8 show that, HRSW basis narrows from December to mid-June and then begin to widen after mid-June. This is because cash prices usually fall to their lowest during November and then rise gradually during the storage season. The difference in the basis values across locations presumably reflects local supply and demand factors, transport costs and storage costs.

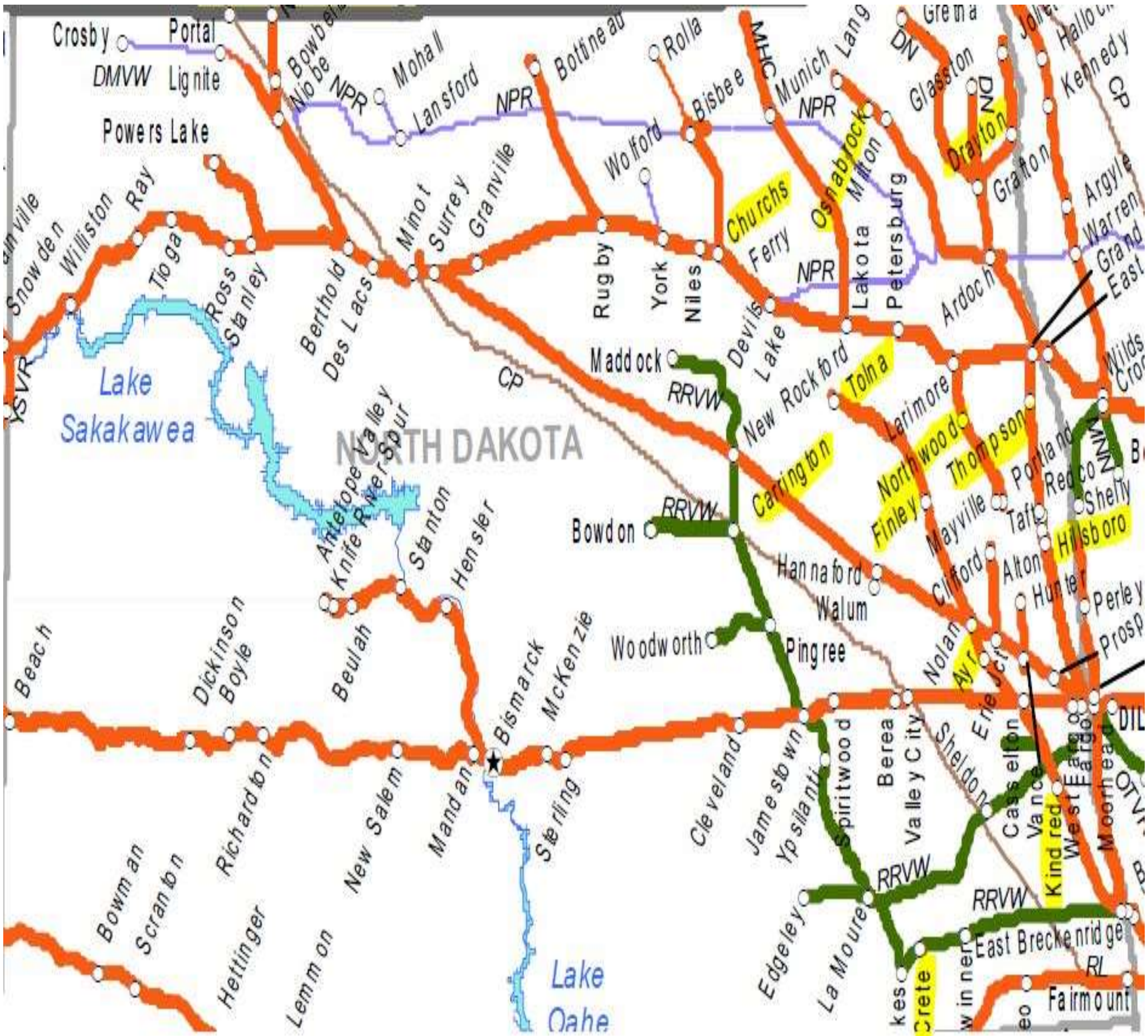

Figure 2. Position of the Elevators Near Rail Road (Marked in Yellow)

Table 2

Summary Statistics- Southeast Region Basis

Elevator	Mean	Standard Deviation	Minimum	Maximum	Count
		Corn			
Arthur Companies	-55.22	32.05	-110	95	209
Central City Grain	-66.60	34.62	-121	90	204
Alton Grain	-55.42	31.60	-110	100	201
Full Circle Ag.	-56.96	32.34	-101	85	199
Finley Farmers	-62.04	30.43	-119	80	205
Dakota Ag. Co-operative	-62.04	30.43	-119	80	205
		Soybean			
Arthur Companies	-77.17	41.64	-184	169	206
Central City Grain	-87.62	39.80	-190	149	208
Alton Grain	-75.92	39.17	-170	170	209
Full Circle Ag.	-80.50	37.47	-140	169	199
Finley Farmers	-86.14	39.68	-192	140	199
Dakota Ag. Co-operative	-72.61	38.62	-160	179	205
		Hard Red Spring Wheat			
Arthur Companies	-58.44	15.88	-84	-24	209
Central City Grain	-57.00	20.03	-91	10	208
Alton Grain	-38.95	20.23	-70	10	201
Full Circle Ag.	-51.79	14.72	-75	-10	202
Finley Farmers	-48.52	19.49	-87	-5	203
Dakota Ag. Co-operative	-46.50	16.14	-78	-5	206

Table 3

Summary Statistics- Northeast Region Basis

Elevator	Mean	Standard Deviation	Minimum	Maximum	Count
		Corn			
BTR	-78.56	32.30	-165	55	201
Thompson Farmers	-74.33	27.20	-125	55	207
CHS Drayton	-69.33	29.15	-120	75	203
Equity Co-op	-66.27	34.71	-120	90	209
Osnabrock Farmers	-80.34	37.63	-140	50	206
Northwood Farmers	-69.95	29.94	-120	60	209
		Soybean			
BTR	-108.97	47.32	-334	-26	207
Thompson Farmers	-110.77	46.62	-344	-44	200
CHS Drayton	-123.01	69.72	-375	-29	209
Equity Co-op	-95.33	39.45	-196	119	209
Osnabrock Farmers	-85.66	45.78	-278	144	197
Northwood Farmers	-99.50	41.53	-215	115	209
		Hard Red Spring Wheat			
BTR	-56.78	22.54	-116	13	209
Thompson Farmers	-46.06	21.66	-103	9.5	208
CHS Drayton	-43.20	22.78	-85	15	207
Equity Co-op	-57.34	20.28	-92	0	209
Osnabrock Farmers	-41.40	25.86	-89	30	204
Northwood Farmers	-52.31	21.64	-95	5	209

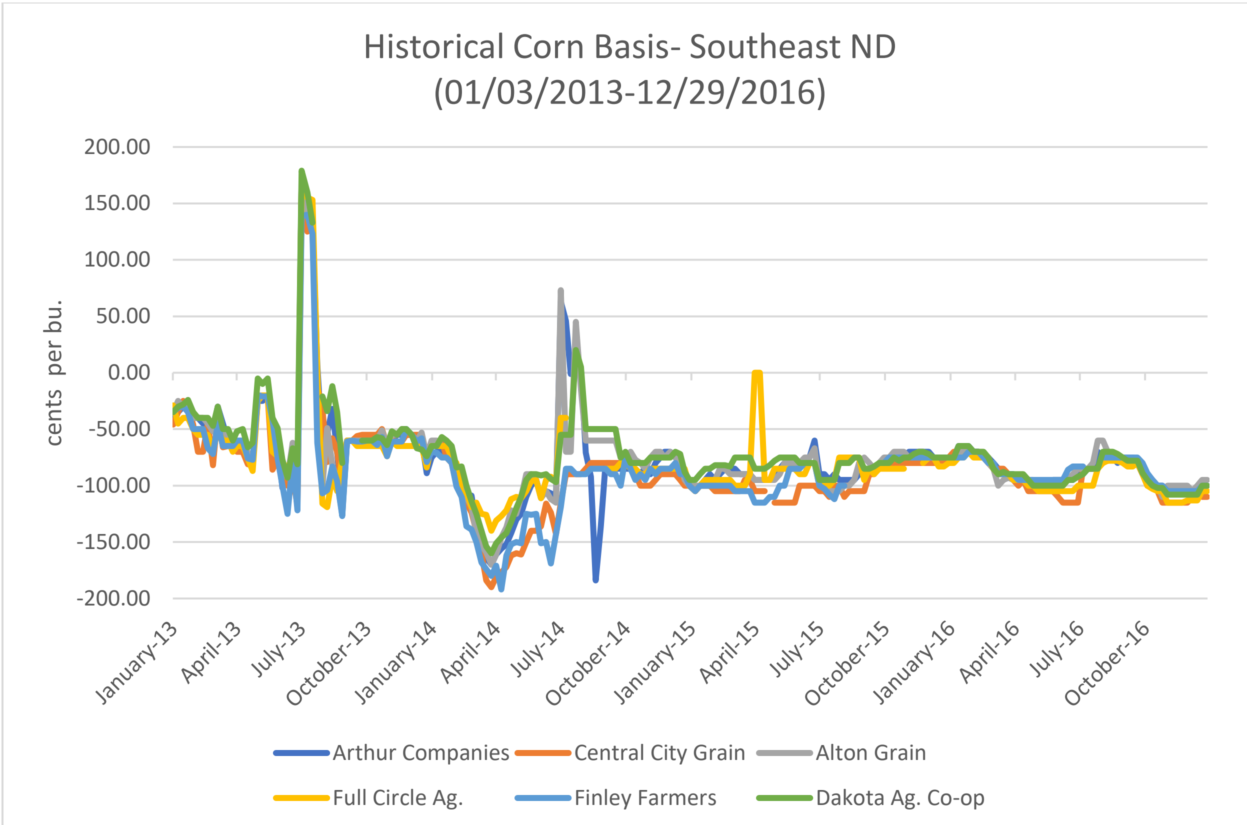

Figure 3. Historical Corn Basis- Southeast ND

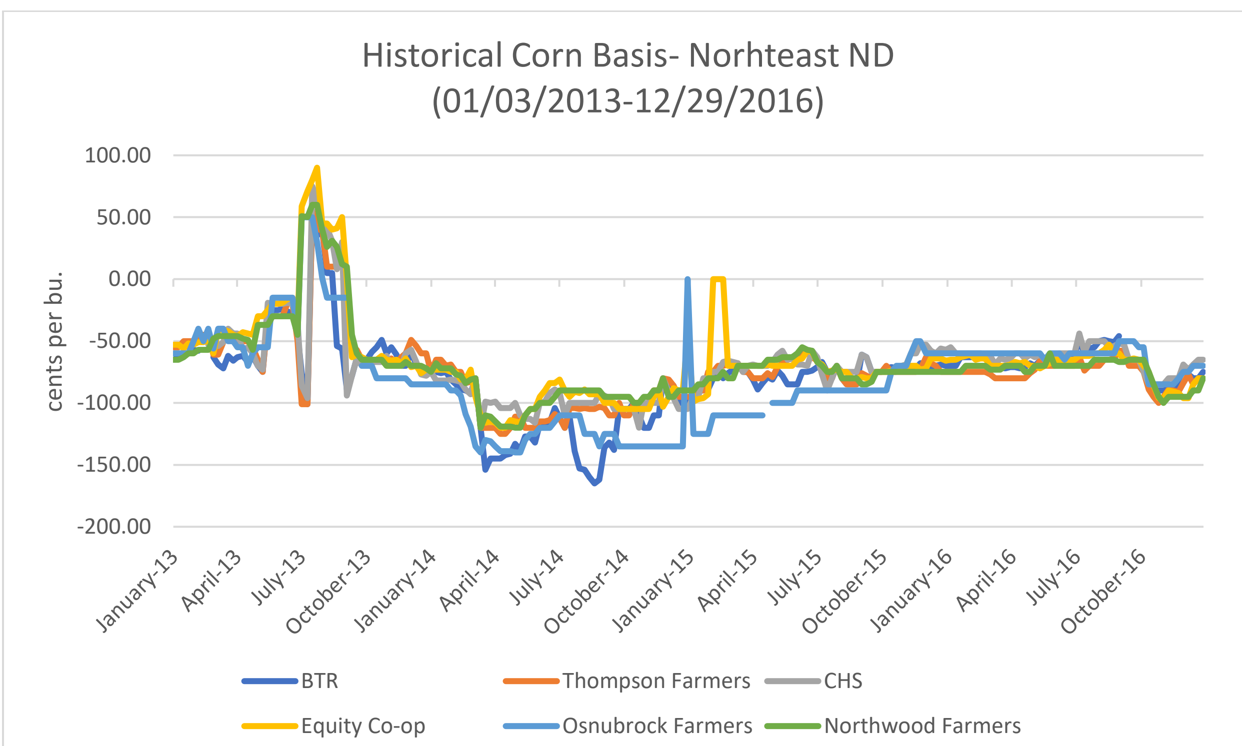

Figure 4. Historical Corn Basis- Northeast ND

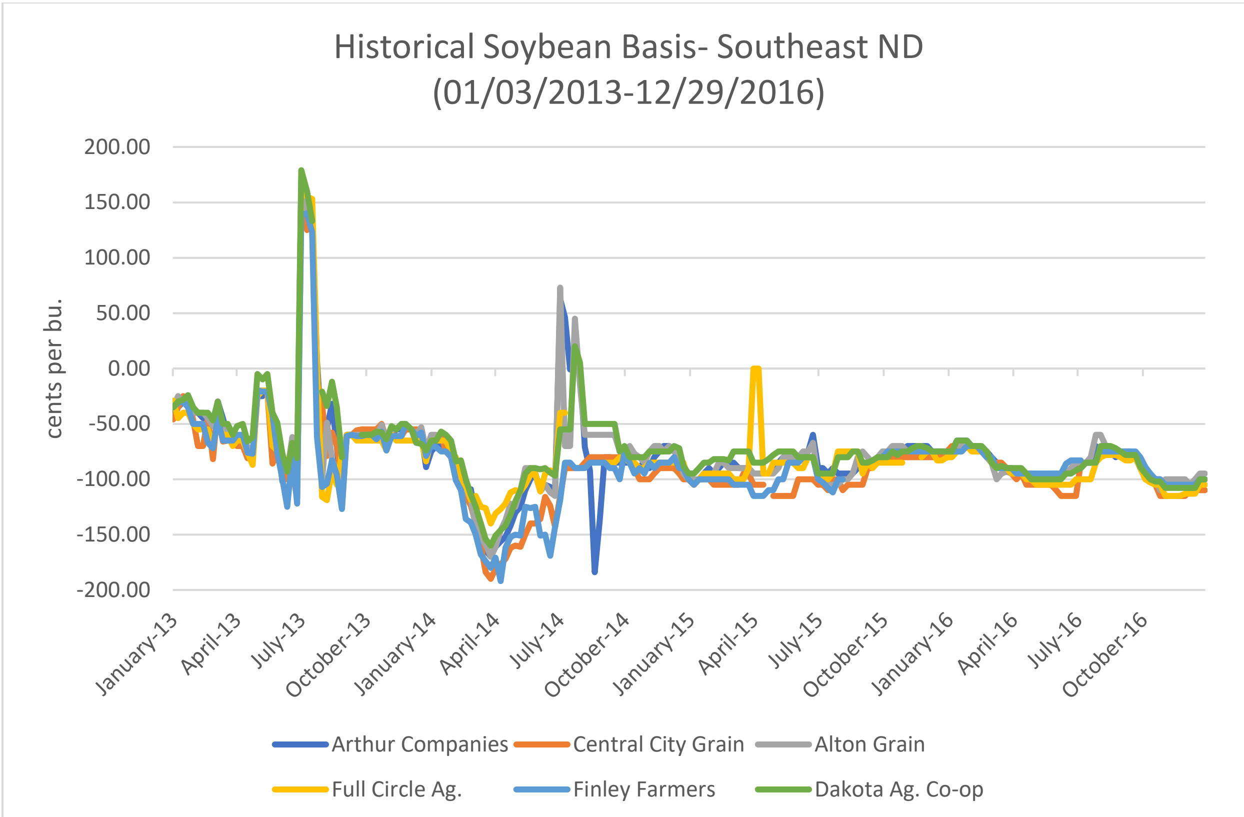

Figure 5. Historical Soybean Basis- Southeast ND

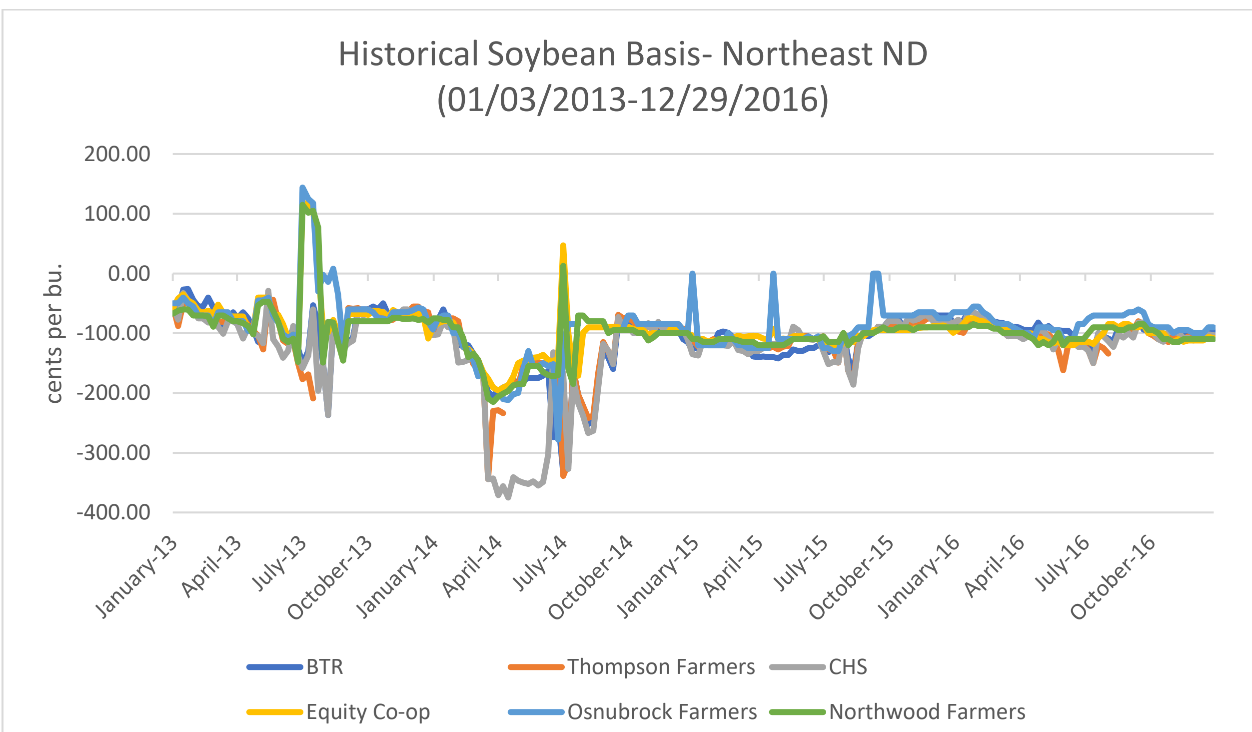

Figure 6. Historical Soybean Basis- Northeast ND

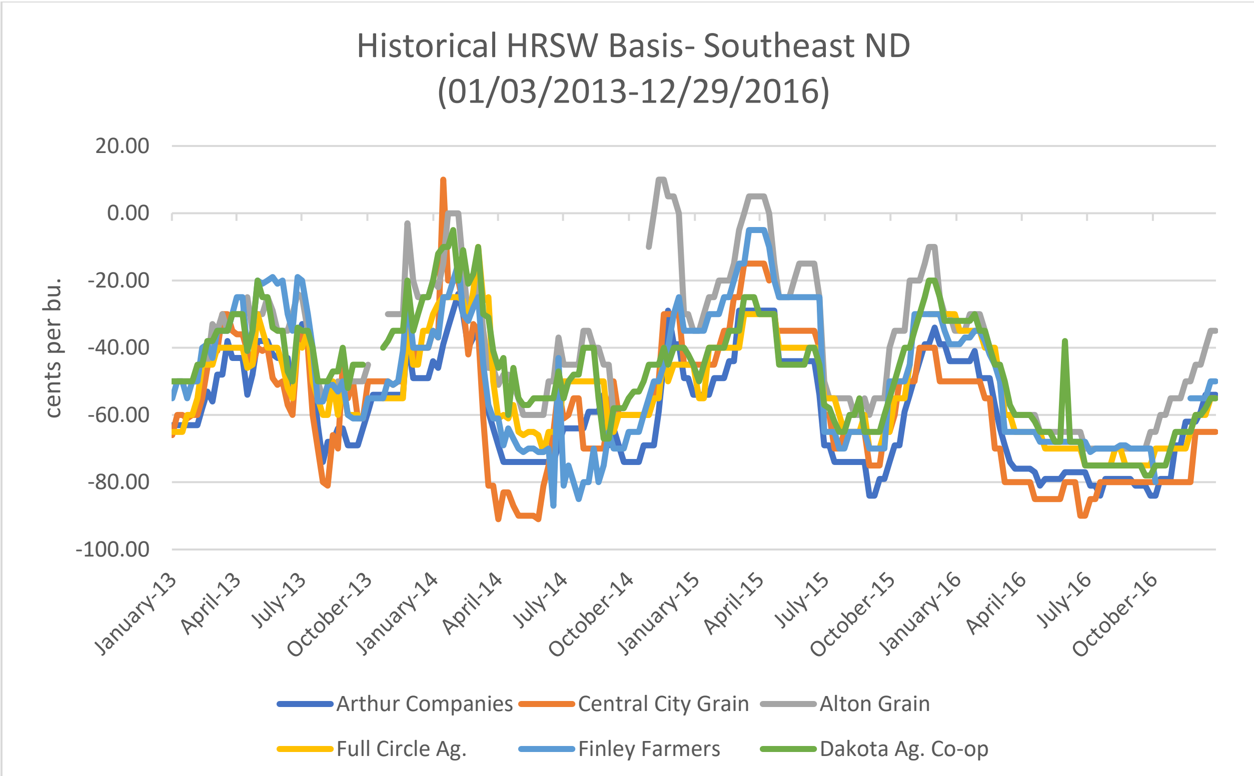

Figure 7. Historical HRSW Basis- Southeast ND

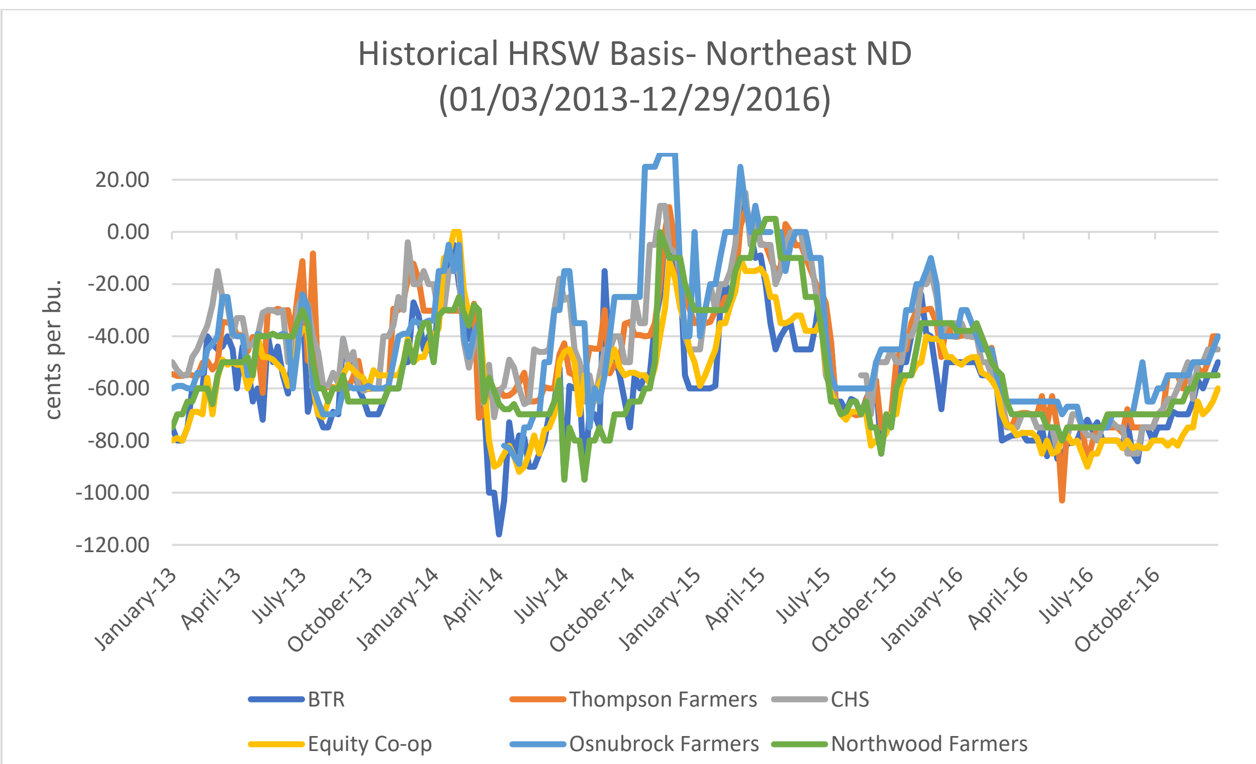

Figure 8. Historical HRSW Basis- Northeast ND

Table 4

Summary Statistics- Terminal Market Bid

Variable	Mean	Standard Deviation	Minimum	Maximum	Count
Corn/cents per bushel					
Gulf Bid	62.77	22.23	30	192.50	209
PNW Bid	108.78	31.15	70.50	259.75	209
Soybean/cents per bushel					
Gulf Bid	78.73	30.60	-3	247.50	209
PNW Bid	114.67	34.89	44	219.50	209
HRS Wheat/cents per bushel					
MPLS	27.57	20.29	-5	85	208
PNW Bid	155.22	70.79	75.50	359.50	209

Terminal market basis for corn, soybean and HRSW are shown in Figures 9, 10 & 11. Summary statistics are reported in Table 4. Terminal market basis for corn and soybean were collected from both Bloomberg and Thompson Reuters. HRSW 20 day-t- arrive truck bids (MPLS) and 30 day-to-arrive rail bids (PNW, Oregon) were collected from USDA, AMS's market news portal.

Gulf basis for corn was relatively stable during the period of examination. PNW basis for corn were also stable with the exception of several extreme bids occurred in the second half of 2013.

Both the terminal markets basis of soybean followed a similar pattern of peak to trough- stronger basis values during July-November period and relatively weaker basis during the rest of the year. An increased volatility is discernible in both markets for soybean. Year to year variation in harvest basis was also extreme at some point of time. It spiked to 219 cents in mid- August of 2014. It again moderated downward in late November 2014 and into 2015 reaching lows.

Basis was noticeably variable for HRSW during the observed period. For example, in late August 2014, the PNW HRSW basis was 160 cents, it spiked to 360 cents in late November of

2014 but then it went downward to 85 cents in July 2015. Basis at PNW is normally higher than MGEX basis. This is because of the transportation availability and costs between two markets, differences between end-users and other supply-demand factors unique to these markets.

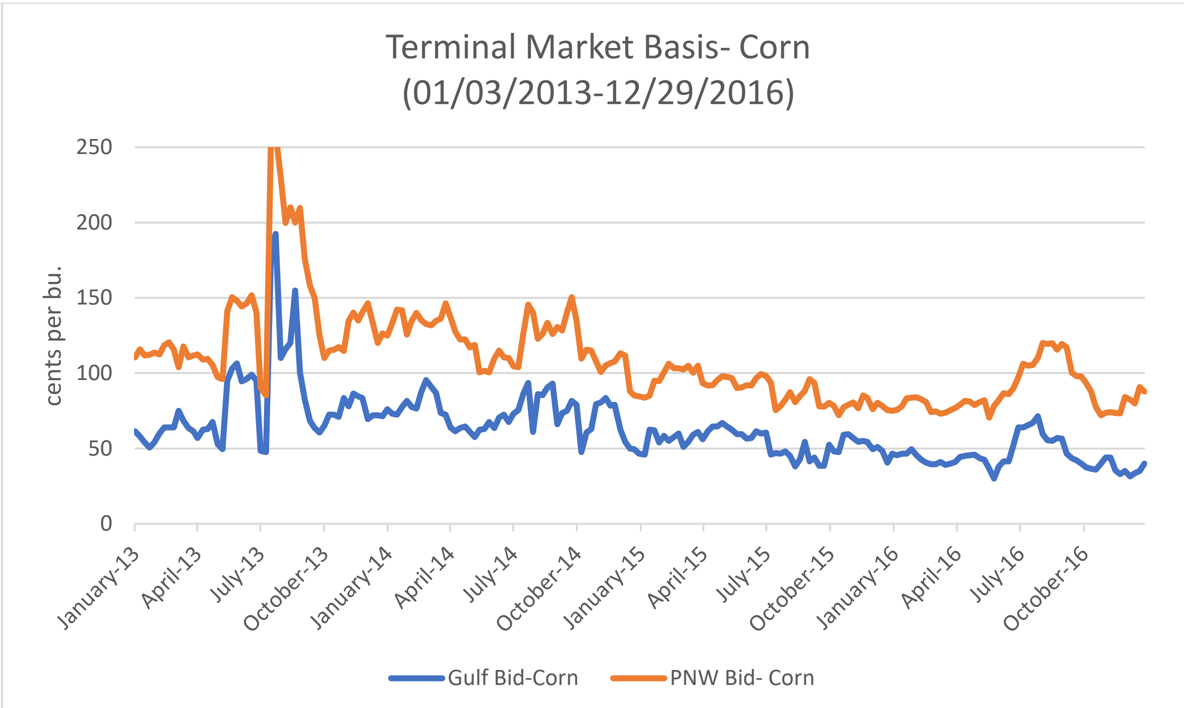

Figure 9. Terminal Market Bids- Corn

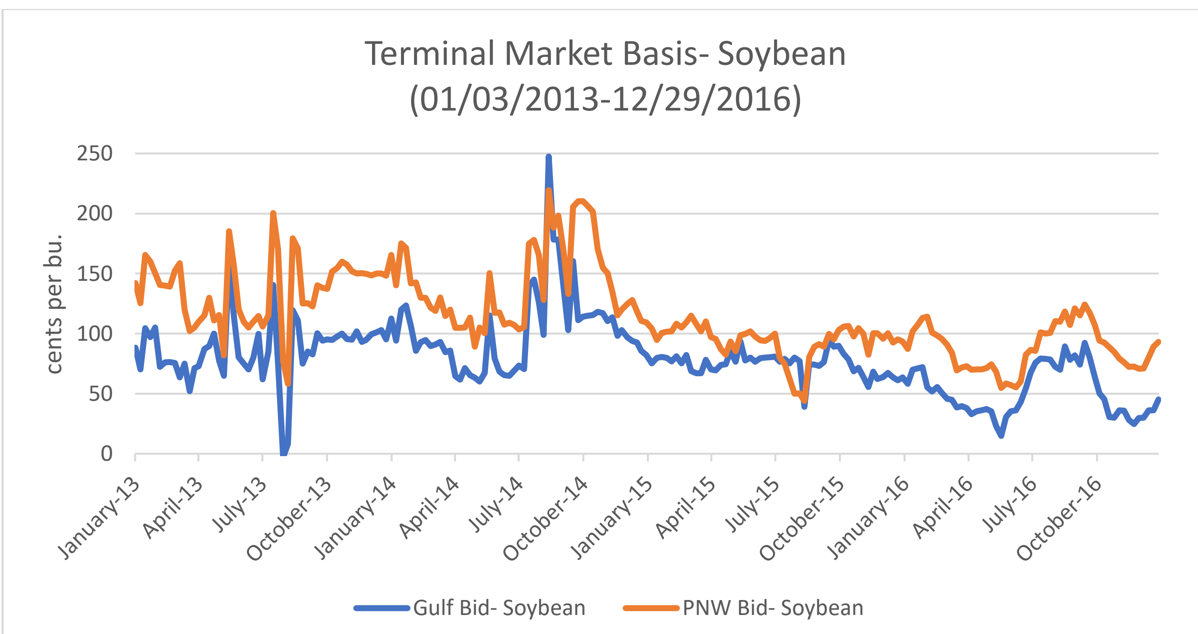

Figure 10. Terminal Market Bids- Soybean

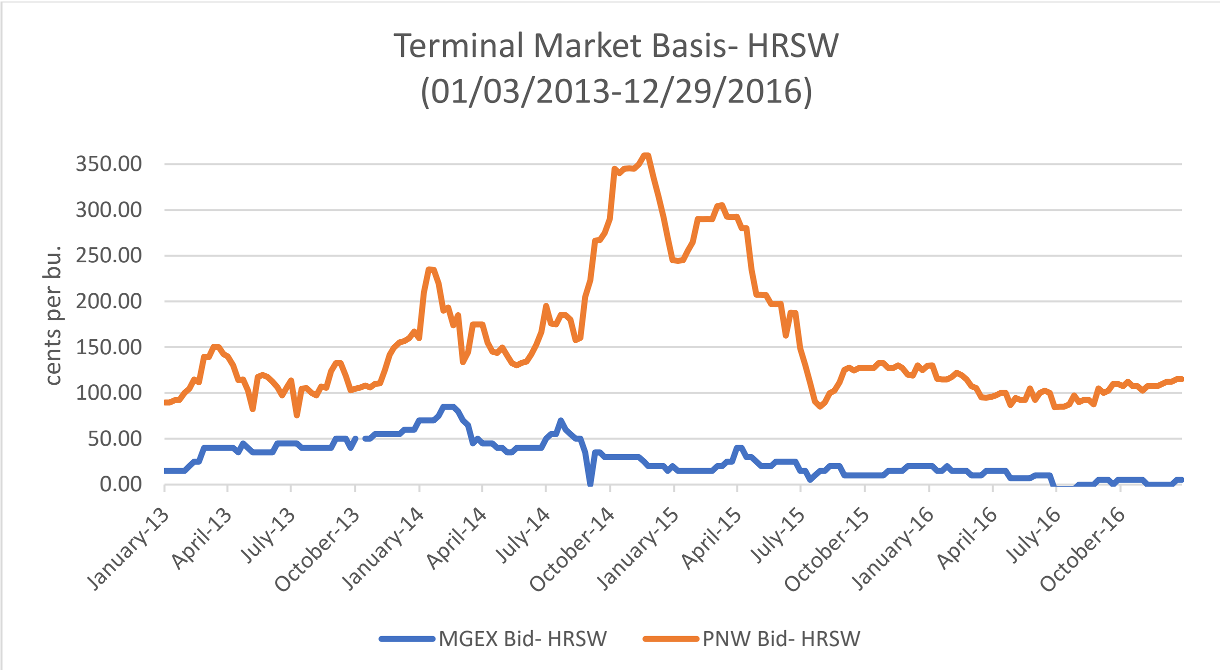

Figure 11. Terminal Market Bids- HRSW

3.2. Premium Basis

The variable *Premium Basis* marks a period (for corn- July 2013 to August 2013 and for soybean- July 2013) when North Dakota's old crop year was winding down to its final months, and the dwindling stocks continued to support near record basis levels. This happened due to excessively tight old crop inventories and the buoyant expectations for a record breaking new crop harvest. To capture the effect of this exceptional period on basis volatility and to obtain more deterministic estimates of the model, this dummy variable is considered. This variable was not required for the spring wheat basis analysis.

3.3. Seasonality

Both the demand and supply of grain follows a seasonal pattern and have an impact on basis. Planting and harvesting periods provide markets with important information regarding expected grain supplies and are likely to increase price volatility (Karali et al. 2009). Declining inventory right after the harvesting period also adds a seasonal characteristic to the grain price volatility. To capture the seasonality, quarterly dummy variables were used in this research. Three quarterly dummies were considered- Spring (March-May), Fall (September- November) and winter (December-February). These periods were determined based on the report[4] on field crops usual planting and harvesting dates published by USDA, NASS and are consistent with USDA price and crop inventory reporting cycle.

3.4. Transport Costs

Shipments from the elevator to the buyer can be made via single-car (normally involving 1-24 cars), multi-car (normally involving 25-49 cars), unit-car (normally either 50, 75 or 110-car) trains, or shuttle-trains. To approximate elevators' total weekly cost for shipping grain by rail we considered both non-shuttle (non-shuttle bids include both unit train and single car bids) and shuttle secondary railcar market auction prices and primary rail market's grain tariff rates, including fuel surcharges. Primary market tariff rates can be adjusted by the railroads once per month. Furthermore, railroad companies are required by law to give a 20-day notice prior to changing tariffs. The data series on tariff rates and fuel surcharges are constructed based on the representative grain corridors. For corn, the Sioux Falls, SD to PNW[5],was used. For soybean, the Fargo, ND to Tacoma, WA rate was used. For wheat, the Grand Forks, ND to Portland, OR rate was used. Historical tariff rates were obtained from the USDA, Grain Transport Report database.

As stated earlier, based on demand, services bought in the primary rail service market may be resold in the secondary rail service market. This characteristic of secondary rail service market, makes it a better indicator of marginal rail service demand for grain transportation. Figure 9 shows the winning bids per car for Burlington Northern Santa Fe Railway's (BNSF) current

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[4] See USDA, NASS Agricultural Handbook No. 628 at http://usda.mannlib.cornell.edu/usda/current/planting/planting-10-29-2010.pdf

[5] Tariff rates for ND to PNW pair is not available so as proxy SD-PNW pair was considered

month and deferred month (February delivery traded in January) non-shuttle and shuttle services trading in the secondary railcar market. The bids represented either a premium or a discount to the regular tariff rates. Supply and demand for secondary rail service is connected to the agricultural production seasonality. This seasonality is apparent in the graph (Figure 12).

Although fuel services charges and rail tariff are adjusted monthly, secondary rail market can fluctuate daily. The period between September 2013 to November 2014 in Figure 12 indicates an upward shift in the bids. This fluctuation was caused by a serious of unexpected service disruptions. On the other hand, changes in rail tariff and fuel surcharges are moderate (Figure 13).

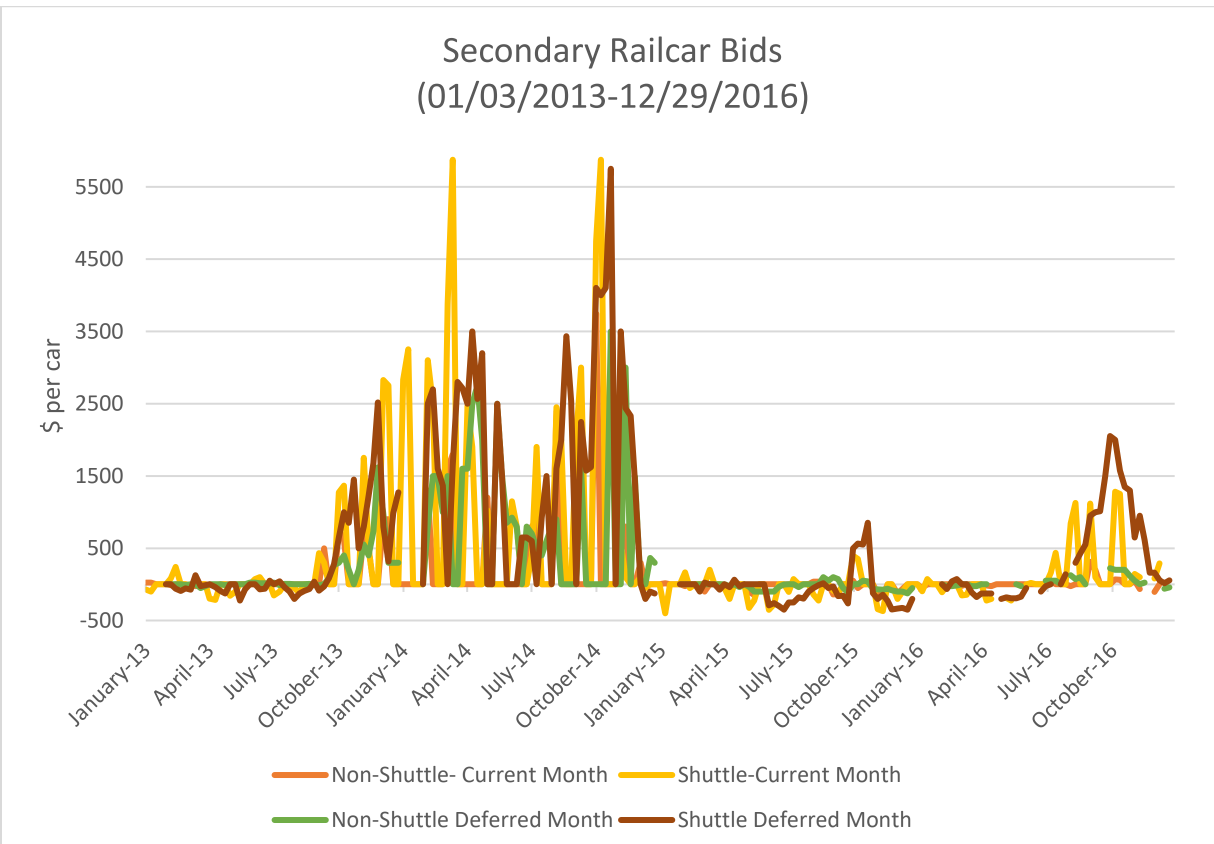

Figure 12. Secondary Railcar Bids

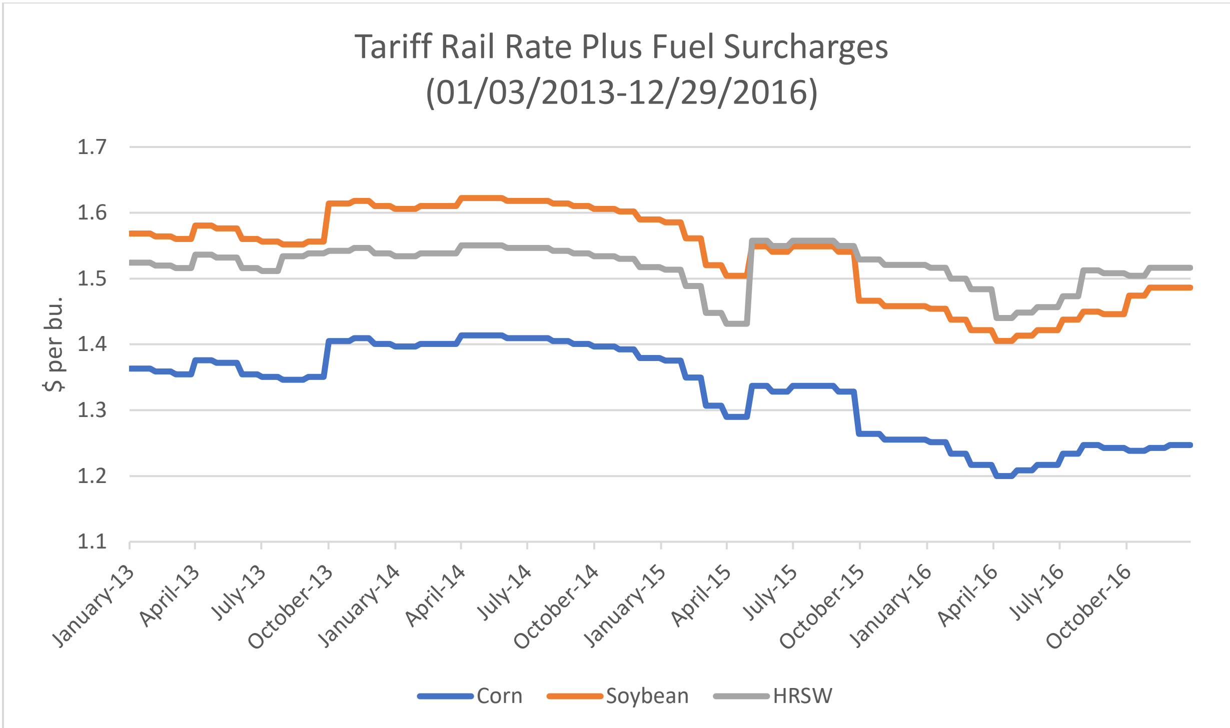

Figure 13. Tariff Rail Rate Plus Fuel Surcharges

3.5. Export Sales

Historically the United States has been s significant exporter of corn, soybean and wheat. As stated earlier, basis is affected by supply and demand conditions, thus variations in export demand also affect basis. Historical data on U.S. export sales of corn, soybean and wheat reported weekly (Friday through Thursday) were used in the analysis. Data were collected from USDA, Foreign Agricultural Service (FAS) database. High variability of soybean export sales compared to corn and HRSW export sales is discernible from Figure 14. The reaction of the market (changes in the basis values) to the variation in the export volume are never instantaneous. This slowness may be because of the time delays in the transmission of the information. To incorporate the feedback over time, three lags of the current export sales were considered.

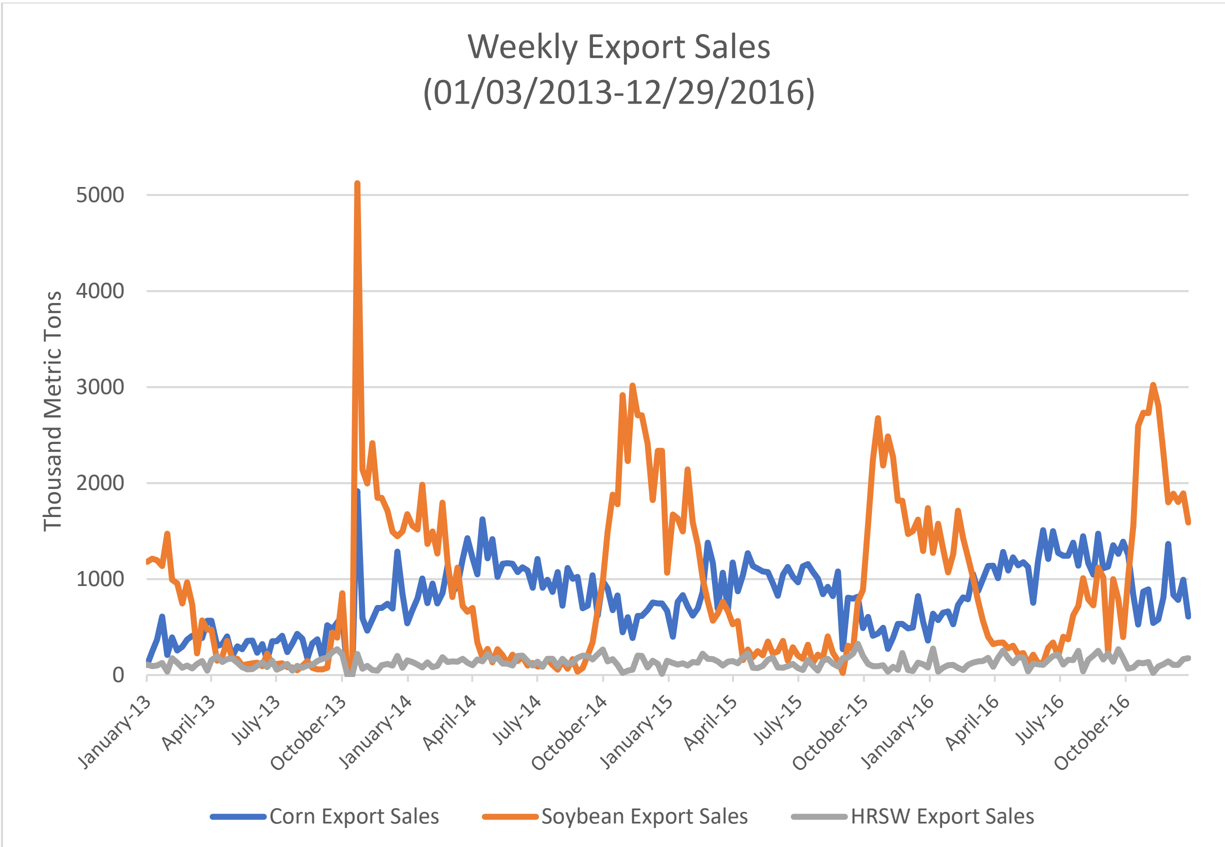

Figure 14. Weekly Historical Export

3.6. Nearby Futures

Nearby Chicago Board of Trade (CBOT) corn and soybean futures prices and nearby Minneapolis Grain Exchange (MGEX) Hard Red Spring Wheat (HRSW) futures price were used in creating the nearby futures price series. All the futures price quotes were collected from USDA, market news service.

The futures market price will have an impact on basis levels as it reflects the overall supply-demand situation in the U.S. market. Figure 15 summarizes the daily settlement price for nearby corn, soybean and wheat contracts between January 2013 and December 2016.

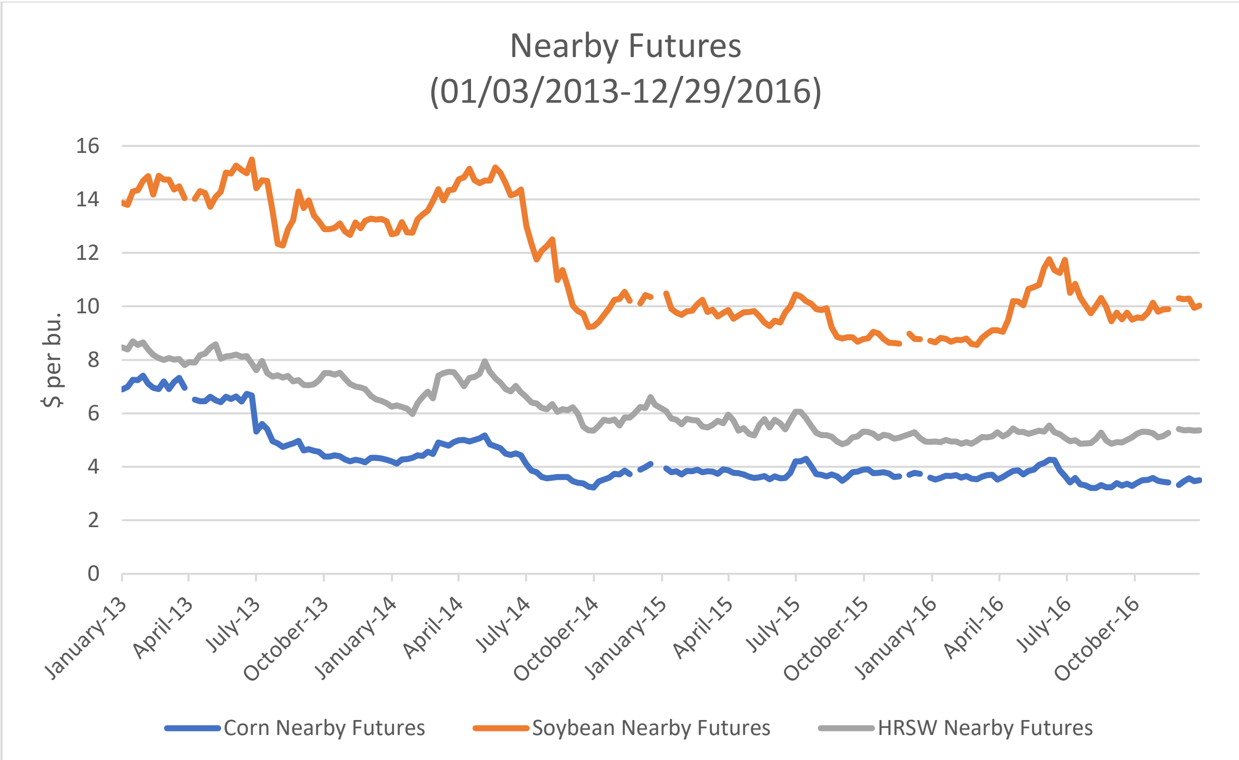

Figure 15. Nearby Futures Price

Both Corn, soybean and wheat display a general pattern of seasonal variability in prices. For all three commodities, a variability peak occurs in late June. The reason may be the uncertainty surrounding the true extent of plantings and likely yield outcomes for these crops. Typically, corn planting starts from late April and continues to late May, harvesting starts at late September and continues until early December. Soybean harvest period starts in late September, reaches a peak in October and finishes in the early or mid-November. Hard red spring wheat is planted from April through late May and harvested in August to mid-September. Therefore, in a broad sense, it can be denoted that the November contract is the new crop contract for soybean, the July contract is the new crop contract for wheat, and the December contract is the new crop contract for corn. Figure 15 also exhibits two peaks for these two crop types (Soybean and

HRSW), the first is a weak early season peak occurring in October-November and strong peak occurring in June-July.

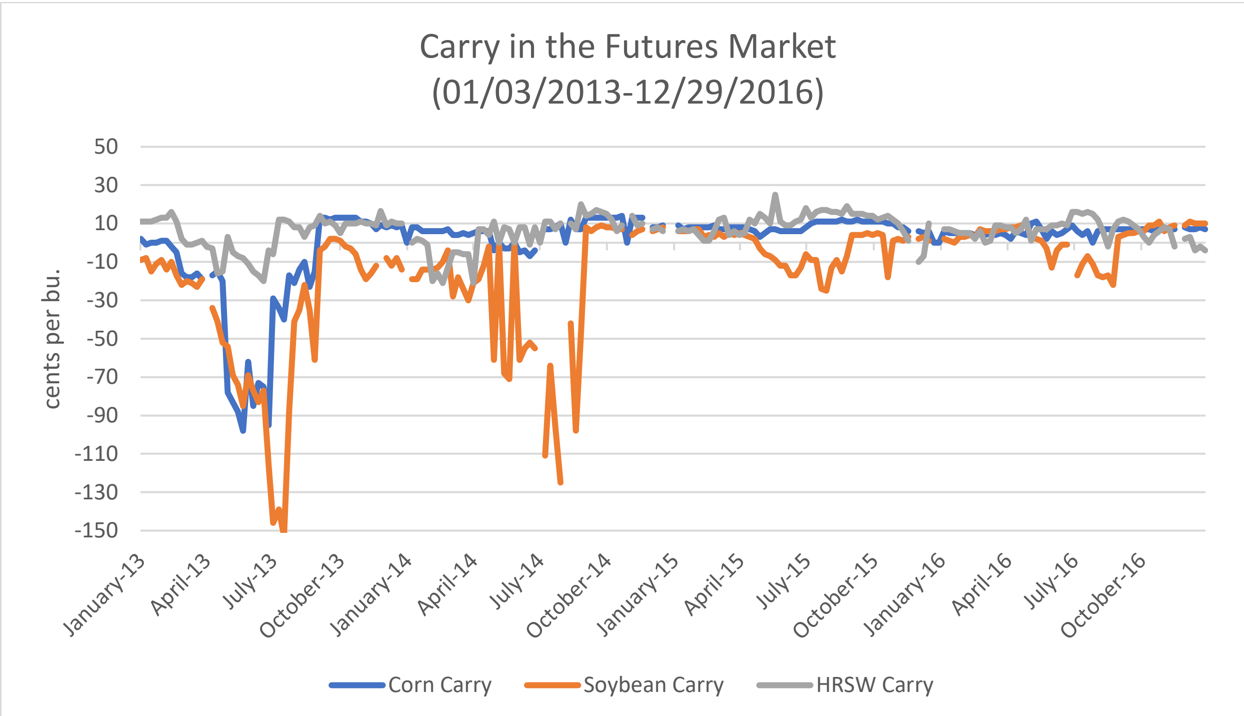

Figure 16. Carry in the Futures Market

3.7. Carry in the Futures Market

Carry in the futures market (Figure 16) can be denoted as the difference in the prices between different futures contracts with different delivery dates. In this research, carry has been calculated as the difference in price between nearby futures contract and the next deferred contract. For instance, on January 3, 2013 the nearby corn contract (March 2013) settled at \$6.89/bu. and the first deferred month to the March contract- the May 2013 corn contract settled at \$6.91/bu. the difference of 2c is the positive carry. Carry in the futures market is typically considered as the economic incentive for storage and it may have an impact on nearby basis. For example, a higher price for deferred contract compared to nearby contract means that the market is willing to pay a premium for the stored grain. Wide carries reflect excess grain supply in the market which may be associated with weak basis levels.

A summary of each variable used in this research are provided in the Table 5.

Table 5

Variable Name

Variable Name	Definition	Unit
Premium Basis	A dummy for capturing the effect of premium basis levels on volatility.	Cents per bushel
Sep-Nov	A dummy for capturing the effect of fall basis levels on volatility.	Cents per bushel
Dec-Feb	A dummy for capturing the effect of winter basis levels on volatility.	Cents per bushel
Mar-May	A dummy for capturing the effect of spring basis levels on volatility.	Cents per bushel
Gulf Bid	Export Terminal basis.	Cents per bushel
PNW Bid	Export Terminal basis.	Cents per bushel
MPLS Bid	MGEX to arrive truck bid.	Cents per bushel
Export	Weekly export sales	Thousand metric ton
Export-1	Lag 1 of weekly export sales to estimate the short and long-run effects.	Thousand metric tons
Export-2	Lag 2 of weekly export sales to estimate the short and long-run effects.	Thousand metric tons
Export-3	Lag 3 of weekly export sales to estimate the short and long-run effects.	Thousand metric tons
ND Tariff FSC	Represents base price of freight rail service originating from ND together with fuel surcharges.	$ per bushel
Non-Shuttle-T0	Non-Shuttle (includes Unit train and single car) bids/offers at current month.	$ per car
Shuttle-T0	Shuttle (100 or more car space) bids/offers at current month.	$ per car
Non-Shuttle-T1	Non-Shuttle (includes Unit train and single car) bids/offers for deferred month.	$ per car
Shuttle T1	Shuttle (100 or more car space) bids/offers for deferred month.	$ per car
Carry	Spread between futures month (nearby and deferred futures)	Cents per bushel
Change in NF	Change between nearby futures price quotes (T_0-T_{-1}).	Cents per bushel

CHAPTER 4. METHODOLOGY

This chapter discusses both theoretical and empirical foundation of the methodology used for this research. Based on the theoretical notion empirical model has been constructed to measure the spatiotemporal volatility of North Dakota basis.

4.1. Theoretical Approach

Understanding the basis volatility is particularly important for grain elevator managers to manage price risk because they are the basis traders and it accounts for most their profit. But basis volatility has great implications for farmers too. Based on the temporal and spatial movement of basis, farmers can make important investment decisions such as investing in storage or transportation. As stated earlier, basis movements are mostly seasonal and greatly depend on grain movement. That is why basis is typically wide during harvesting period as during this period transport costs are typically high and supply is abundant which gives market incentives to store. Based on different market opportunities different market also influences basis level. For example, an area with heavy corn/soybean/HRSW concentration will have wide basis as the supply is copious.

This project focuses on investigating the spatiotemporal variations in commodity basis of Southeast and Northeast region of North Dakota. Assuming volatility of the basis of the regions studied is related with transportation costs, storage incentives, production and stocks and local economic conditions, following linear relationship has been modeled in the equation.

$$Basis_{it} = \int \begin{matrix} Transport\ cost_{it}, Storage\ Incentive_{it}, Export\ Sales_{it}, Terminal\ Bids_{it}, \\ Seasonality_{it}, Premium\ Basis_{it} \end{matrix}$$

Here, the subscript *i* stands for i^{th} location and *t* represents time.

Likelihood-based approach was used to create linear mixed models for this equation. Mixed model analysis is considered one of the most sophisticated methods for analyzing correlated data. Mixed models allow a wide variety of variance-covariance structures to be modeled because these models use both fixed and random effects in the same analysis. This model will allow us to quantify basis movement including both time and elevator location and thereby help manage basis and investment decisions. In this case, a traditional two-way analysis of variance is used to examine spatial relationships between local elevator basis and a set of associated attributes for each year and the temporal variations in the coefficients are obtained through a series of independent cross-sectional estimations. The basic assumption here is that the data are linearly related to the unobserved multivariate normal random variables.

There are different guidelines for building mixed models, all of those have the same goal- to estimate the most efficient model that best fit the data. As the objective is to estimate spatiotemporal variation in the basis movement, an unconditional model (a model with no predictions) has been estimated to calculate the intra-class correlation coefficient (ICC). Based on model building approaches, fit statistics (which are used to assess model fit) also differs. Jennrich and Schluchter (1986) states that likelihood based methods are the best way to estimate covariance parameters in the mixed model. In this paper, all three basis models were estimated using Maximum Likelihood (ML) to better examine the improvement in the model fit using Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC) when the models differ in fixed effects. For both criteria, smaller values indicate better fit.

4.2. Empirical Approach

A time series statistical procedure to model basis responsiveness for elevator, i is represented in the following equation:

$$y_t = \alpha + \beta^m x_t^m + \varepsilon_t$$

Here y_t represents the $1 \times t$ solution vector of price basis, x_t^m represents a $m \times t$ matrix of exogenous variables explaining price basis with $t = \{1, \dots T\}$ representing the temporal dimension and $m = \{1, \dots M\}$ the set of exogeneous variables, α is the intercept, β^m is the associated parameters of exogenous variables; ε_t is the remaining random error. Equation (2) is estimated for each elevator.

In traditional linear model, distributional assumption about the error term ε is often too restrictive (SAS User Guide 2009). Mixed model more flexibly specifies the covariance matrix of ε as it allows for both correlation and heterogeneous variances assuming normality of both fixed effect parameters β and random effect parameters γ. Based on this notion the general linear mixed (GLM) model can be written as

$$y = X\beta + Z\gamma + \epsilon$$

This GLM model has additional components that traditional linear model ignores. This include the design matrix Z that can be a continuous or dummy variable. The γ and ε are assumed as normally distributed with

$$E\begin{bmatrix}\gamma \\ \varepsilon\end{bmatrix} = \begin{bmatrix}0 \\ 0\end{bmatrix}$$

$$VAR\begin{bmatrix}\gamma \\ \varepsilon\end{bmatrix} = \begin{bmatrix}G & 0 \\ R & 0\end{bmatrix}$$

The variance of y can be written as

$$V = ZGZ' + R$$

Shaik & Bhattacharjee (2015) estimated and compared the times-series, panel and hierarchical linear models' spatial random variation in 20 US crops across 48 states using county level data. They have estimated on-way, two-way and three-way panel and hierarchical linear models. Here, a two-way random effect model, specified by them is used to estimate the covariance parameters linked to variation associated with spatial (across elevators) and temporal (time):

$$y_{it} = \alpha + \beta^m x_{jk}^m + z_i + z_t + \varepsilon_{it}$$

Here z_i represents random error associated with elevator location, z_t represents temporal random variation, ε_{it} represents remaining residuals; α is intercept and β^m is the slope of the predictor x_{it}^m. The covariance parameters estimated will provide the temporal, spatial and remaining variances. These variances are used in the computation of spatial variation (variation across elevators) and temporal variation (variation over time) using Intra-class Correlation Coefficient (ICC). It can be represented as-

$$ICC = \frac{\sigma_\alpha^2}{\sigma_\alpha^2 + \sigma_\varepsilon^2}$$

This research uses SAS based PROC MIXED statements with estimation method defined as Maximum likelihood. PROC MIXED constructs an objective function associated with Maximum Likelihood (ML) and maximizes it over all unknown parameters.

CHAPTER 5. RESULTS

As noted earlier, to understand the basis volatility dynamics, three crops of North Dakota- corn, soybean and hard red spring wheat (HRSW) were considered. This chapter reports effects of potentially influencing predictor variables on local basis quotes of these three crops. Before employing the mixed effect approach, each elevator's basis model was estimated by traditional OLS to produce fit statistics. Mixed effect method used in this research can be best understood in terms of two level regressions. The first level is the individual fixed effect estimation for each elevator and second level is panel analysis, which explains the variation in basis across time and elevator location. A panel data set has been developed to observe the random effects of time and elevator locations. The purpose of the panel modeling is to estimate the variability of basis overtime across elevator locations. This kind of estimation also generates necessary covariance parameters which allows to compute intra-class correlation coefficient (ICC). ICC quantifies the unobserved determinants of the basis model in terms of time, location and residuals.

5.1. General Model Fit

Favorable soil types, topography and climate make the Southeastern part of North Dakota more suitable for corn and soybean production. On the other hand, the Northeastern part of the state contains a remarkable concentration of hard red spring wheat. Based on this crop concentration and differences in local processing, two models were estimated to determine the basis volatility. First model comprises of locations in Southeast North Dakota and second model is built around locations of Northeast region.

Table 6 shows the general model fit of the com, soybean and HRS wheat models for both regions of North Dakota. The root mean square error (RMSE) of different model specifications show the differences in the model fit. The adjusted R-squared statistic shows that these models have a good fit. In general, the individual location corn models explain 63-89% of the variation of corn basis, the soybean models explain 48-77% of the total soybean basis variation and the HRS wheat models explain 56-71% of the wheat basis variation.

The RMSE statistic helps to understand a complete picture of the error distribution. For corn, average RMSE for Southeast region is 14.26 and for Northeast region, it is 16.43. This suggests that corn models for Southeast region has a better fit compared to the models of Northeast region. For soybean, average RMSE is 24.77 and 35.93 for the Southeast and Northeast regions respectively. For wheat, is the average RMSE is 10.53 and 13.90 for Southeast and Northeast regions respectively. Southeast soybean basis ranges from -192 to 179 and Northeast soybean basis ranges from -375 to 144. Based on the RMSE averages it is obvious that Southeast region basis models explain basis behavior better than Northeast region's models. The reason is the low standard deviation of the unexplained variance of Southeast basis model.

Table 6

Adjusted R2 and RMSE of Corn, Soybean and HRS Wheat Basis Model for Southeast and Northeast Region

Southeast North Dakota						
			Corn			
	Arthur Companies	Alton Grain	Central City Grain	Finley Farmers	Dakota Ag. Cooperatives	Full Circle Ag.
R^2	0.87	0.86	0.87	0.70	0.85	0.89
RMSE	13.13	13.21	14.04	18.68	14.28	12.23
			Soybean			
R^2	0.64	0.64	0.67	0.63	0.77	0.70
RMSE	27.37	25.32	25.25	27.02	20.93	22.70
			Hard Red Spring Wheat			
R^2	0.64	0.69	0.60	0.57	0.70	0.65
RMSE	9.63	11.14	12.40	13.35	8.36	8.29
Northeast North Dakota						
			Corn			
	BTR	Thompson Farmers	CHS Drayton	Equity Co-Op	Osnabrock Farmers	Northwood Farmers
R^2	0.63	0.76	0.80	0.83	0.80	0.84
RMSE	21.84	14.91	14.24	16.05	18.18	13.38
			Soybean			
R^2	0.51	0.48	0.54	0.54	0.53	0.54
RMSE	33.21	34.45	52.18	28.88	35.38	31.50
			Hard Red Spring Wheat			
R^2	0.56	0.58	0.62	0.69	0.71	0.58
RMSE	15.27	14.37	14.02	11.24	13.91	14.56

5.2. Corn Basis Model

Table A1 and A2 in Appendix report the fixed effect estimates for Southeast and Northeast North Dakota's corn. Table 7 lists the solution vector for fixed effects estimates of both regions. This is an overall confirmation of the findings listed in Table A1 and A2 in Appendix-A. Table 8 displays Type 3 test for all the fixed effects listed in Table 7. This is an ANOVA style test for each fixed effect. It tests the overall usefulness of the independent variable used in this study.

The reported coefficients for the constants for both the regions are the predicted basis when all predictors take zero value. The intercept is significant at 1% and 5% level.

As stated in the previous chapter, *Premium Basis* identifies a period of positive basis. This period was short lived which is indicative of a strong local demand with supply deficit in that particular time period. Positive coefficient make sense as due to short supply of corn and soybean, elevators in both regions offered cash price higher than the nearby futures prices to attract immediate delivery to their facilities. This variable is significant at 1% level for both the regions. This implies that compared to normal supply-demand period, supply driven markets have significant positive impact on basis volatility. For this reason, elevators included in the models reacted aggressively with lucrative cash prices. For example, during a period of high cash price, Southeastern basis will be 75 cents and Northeastern basis will be 37 cents less negative than a normal North Dakota discount basis quotes.

Three seasonal dummy variables are used in this analysis- spring (*March-May*), fall (*September- November*) and winter (*December-February*) period to adjust for seasonal basis patterns. Analysis reveals that Southeast region's corn basis is significantly variable (10% level) during spring period. Although fall and winter dummies are not significantly affecting the local basis levels but a broad discussion is necessary to comprehensively understand the volatility dynamics of both regions' corn basis.

Table A1 and A2 in the appendix show that basis during the fall season is most negative compared to winter and spring season, which implies decrease in cash price relative to futures price. This is mainly because large supplies are available to the elevators by then. For example, Full Circle's basis is weakest in October (fall)- 13 cents more negative than the normal period basis. By the end of winter period, Full Circle's basis reaches its strongest level (7.87 cents more negative than normal basis) compared to fall period basis.

It is tempting to depict this seasonal variation in basis levels is solely due to large influx of corn in fall and high demand in winter or due to limited supply in spring. But this may not be true always because local basis variation cannot be fully explained in terms of normal supply and demand conditions. A narrow basis cannot be always suggestive of the fact that supply of and demand for the underlying commodity are in equilibrium.

Local basis is often called as the voice of market as it regulates or balance the inflow of grain with the outflow of grain in the local market. But local demand and supply is not the only factor that may create substantial disruption in this "inflow and outflow" system. There at least two major issues that may make up basis. One is transportation costs. Elevators far away from the area where the grain is used or exported are at a disadvantage due to the transportation cost. Any increase (decrease) in transportation cost will be incorporated in the basis quoted by the elevators. Another reason is cost and availability of storage. A large crop may widen basis as it results in a shortage of storage. Elevators may run out of storage and widened their basis because they do not want to put more corn in piles outside.

However, analysis shows that seasonal basis quotes are not significant enough to contribute to the volatility of Northeast region's basis. Two obvious facts behind this difference are- this region grows much less corn than Southeast North Dakota and all the major processors of corn are in Southeast region. These make Southeast's corn basis more stable from period to period compare to Northeast region's basis.

Gulf bids and PNW bids have been considered as destination basis values for corn. The results show that none of the export bids are significant for Southeastern region and only PNW bids are positively significant for Northeast region. The likely explanation for this difference is the variability in the local demand (35% of the Southeastern corn and 3% of the northeastern corn go to the local market: source UGPTI Publication No. 292) for both regions' corn.

With any increase in export bids, regional elevators must respond with a higher cash price if they want corn to flow to their facilities. For ND corn, PNW is an extremely important terminal market. Shipments of corn originating from North Dakota elevators are most often bound for the PNW gateway—with about half of shipments reportedly bound for this market (UGPTI Publication No. 292). The fixed effect estimates of this research also captures the significance of this relationship, analysis shows that one cent increase in PNW bids will strengthen Northeastern ND basis by 0.36 cents. Historically more than 35% of the Northeastern corn are shipped to PNW export facilities, this amount is only 6% for gulf facilities (UGPTI Publication No. 292).

Although the United States is the largest exporter of corn in the world and more than 70% of US corn are shipped from these two port locations, it is not surprising that export bids are not significantly affecting a heavy corn producing area like Southeast North Dakota. One possible explanation for this is the impact of local demand on local basis levels. According to UGPTI publication (No.292), in 2015-16 MY, 35% of the Southeastern corn has been consumed locally whereas only 3% of the Northeastern corn has been consumed by local processor. According to an estimate by the North Dakota Department of Commerce Economic Development & Finance Division[6], almost 60 percent of North Dakota's total corn production is purchased by five ethanol plants (all of them are situated in Southeastern ND) of the state that have the capacity to produce nearly 450 million gallons of ethanol per year. Various studies have shown that ethanol

[6] See http://www.business.nd.gov/energy/Ethanol/

industry's corn purchases have a positive effect on regional corn price. North Dakota ethanol industry provides an additional market and higher corn price for Southeast region's farmers. This price enhancement effects are reflected in the analysis.

Under normal market conditions export sales will positively affect futures price thus it will end up weakening basis. On the other hand, actual export shipments will rally local basis. To test this hypothesis, in the analysis, export sales volume and its lags have been used. The change in the level of export may have important behavioral implications beyond the time in which the actual exports have been made. This is the rationale behind including three lags of exports in both models. The results show that export sales have no significant contemporaneous effect on Southeastern and Northeastern corn basis. But export lags are significant at 5% and 10% level for all two regions. Crop concentration is the factor behind the variations in the effect of export sales and its lags on basis levels. It can be inferred from the analysis that during a month of normal supply and demand (actual export sales and three lags marks a period of 30 days), for additional 1000 metric ton increase in export sales, Southeastern corn basis decreases on average by 0.0085 cents and Northeastern corn basis decreased by 0.0078 cents.

One possible explanation for this is that with the increase in export sales nearby corn futures also is increasing which in turn weakening basis. As stated earlier, static demand and supply conditions (which assumes production and consumption are simultaneous) are not always applicable for basis. In order for traditional supply and demand analysis to explain basis, one must think about changes to supply, demand and prices in a very short time period, typically a matter of days (Dr. Frayne Olson, personal communication, April 8, 2017). Thus, any unexpected increase in exports are likely to increases the price in the futures market. This increase in the futures market will increase the sales volume (supply) of grain sold in the local market. If the local elevator can immediately re-sell grain to an export terminal at a profit (demand), the local basis may not change. However, if the local elevator cannot immediately re-sell the grain to an export terminal at a profit (because they need to purchase additional rail transportation at a premium), the local basis may become more negative.

Results show that *ND Tariff FSC* is significant at 1% level for both regions with expected negative sign. Analysis shows that with one dollar increase in *ND Tariff FSC*, Southeastern ND basis weakens by 0.86 cents and Northeastern ND basis weakens by 2.07 cents. Relatively large impact of *ND Tariff FSC* on Northeastern basis compared to Southeastern basis is due to this region's out of state export orientation. For both regions, except *Shuttle* T_1 (bid auctioned in T period for delivery in T1), none of the secondary market bids are significant. For three of the Southeastern elevators, *Shuttle* T_1 is significant at 1% and 5% level with expected negative sign. For all the locations in Northeastern region it is significant at 1% and 5% level. Southeastern and Northeastern basis decrease by 0.3 cents and 0.6 cents respectively in response to one dollar increase in secondary market deferred bid- *Shuttle* T_1. This is consistent with that of Vachal (2001), who reported that shuttle rate is likely to be strong for corn. This indicates high importance of this option of shipping grain by elevators through paying additional premium for a contract guaranteeing delivery of empty railcars. There are two reason for incurring additional cost for guaranteed rail service one is large harvest and another is unexpected shifts in supply and demand for rail service. During 2013-2014 crop marketing year elevators paid record high premiums in the primary market. Findings captured this insufficient rail capacity and record high corn harvest in 2013 and 2016.

Carry in the futures market or spread between nearby and deferred futures month signals whether market wants grain now or later. Results show that it has the expected negative coefficient and is statistically significant at 1% for both Southeast and Northeast regions. Thus, wide carry in the futures contracts prices is associated with weaker basis levels. The analysis reveals that, one cent increase in carry is associated with weakening of Southeastern and Northeastern basis by 0.35 cents and 0.26 cents respectively.

NF Change is the price difference between two nearby futures quotes. Any increase in futures price is expected to weaken basis. Analysis also reveals that change in the nearby futures price has a negative effect on basis. But the effect of nearby futures is not overwhelming for any of the regions. Out of twelve locations, only four locations' basis are significantly affected (at 5% level) by the change in nearby futures price. This suggests that short term changes in the futures market do not affect local basis levels.

Table 7

Solution for Fixed Effects: Southeast and Northeast Region Corn Panel Model Estimation

Effect	Corn-Southeast	Corn-Northeast
Intercept	72.90**	185.59***
Premium Basis	75.21***	37.35***
Sep-Nov	-5.82	-2.13
Dec-Feb	-1.60	1.04
Mar-May	-5.28*	-4.23
Gulf Bid	0.0820	0.0370
PNW Bid	0.0520	0.3640***
Export	-0.0049	-0.0046
Export 1	-0.0088**	-0.0076*
Export 2	-0.0086**	-0.0075*
Export 3	-0.0088**	-0.0082**
ND Tariff FSC	-85.89***	-206.40***
Non-Shuttle T_0	-0.0005	-0.0013
Shuttle T_0	-0.0014	-0.0008
Non-Shuttle T_1	-0.0026	-0.0011
Shuttle T_1	-0.0032***	-0.0059***
Carry	-0.3542***	-0.2556***
NF Change	-0.0865	-0.0523

Note: *, ** and *** indicate significance at 10%, 5% and 1% level respectively.

Table 8

Type 3 Test for Fixed Effects: Southeast and Northeast Region Corn Panel Model Estimation

Effect	Corn-Southeast	Corn-Northeast
Premium Basis	126.82***	35.22***
Sep-Nov	2.12	0.31
Dec-Feb	0.16	0.08
Mar-May	3.18*	2.27
Gulf Bid	0.68	0.16
PNW Bid	0.46	27.99***
Export	1.11	1.13
Export 1	3.98**	3.41*
Export 2	3.55**	3.04*
Export 3	3.91**	3.93**
ND Tariff FSC	14.92***	98.19***
Non-Shuttle T_0	0.03	0.20
Shuttle T_0	0.91	0.36
Non-Shuttle T_1	1.44	0.29
Shuttle T_1	5.54**	21.10***
Carry	26.59***	15.90***
NF Change	2.03	0.86

Note: *, ** and *** indicate significance of F value at 10%, 5% and 1% level respectively.

Table 9

Overall Fit Statistics for Corn Basis Model

Fit Statistics	Southeast Corn	Northeast Corn
-2 Log Likelihood	6904.9	8061.2
AIC (Smaller is Better)	6946.9	8103.2
AICC (Smaller is Better)	6947.9	8104.2
BIC (Smaller is Better)	6942.6	8098.8

Table 10

Corn Intra-class Correlation Coefficient Estimation

Covariance Parameter	Intra-class Correlation Corn- Southeast	Intra-class Correlation Corn- Northeast
Elevator	12%	11%
Date	63%	27%
Residual	26%	62%

Objective of this research is to temporally and specially classify unobserved basis determinants. Thus, we considered a mixed model approach to estimate how much of the basis volatility may change across elevator location and time. Based on the covariance parameters estimates shown in Appendix Table A7 and A10, Intra-class Correlation Coefficients (ICC) have been developed for this purpose (Table 10). Table 9 reports the overall fit statistics for the corn model of both regions.

ICC estimates indicates that for the Southeast region, 12% of the total variation in basis is accounted for by the elevator locations (space). This variation is similar in magnitude (11%) for Northeast region. But time explains 63% of the total variation in Southeastern basis whereas only 27% of the variance can be marked as temporal variation in the Northeastern basis. This is because of the high magnitude of residual in Northeaster corn basis model. Fit statistics shown in Table 9 also confirms Southeast corn panel model's relative efficiency in explaining basis volatility compared to Northeast corn basis model as likelihood values of all three information criteria are low for Southeast region.

Because of the crop concentration and importance of corn to the elevators crop portfolio in the Southeastern part of the state, Southeastern basis is more likely to be explained by the variables used in the model compared to the Northeastern region, which is light in corn production and usage. This difference between the regions justifies the finding regarding the variance components. Dominance of temporal variation in both corn basis model signifies North Dakota basis's response to actual and anticipated changes in supply and demand conditions. Analysis of this research reveals a very loose seasonality in ND basis. Thus, high temporal variability of basis is primarily caused by the year to year variation in production, (i.e. 2012's national drought, 2016's record production etc.) of corn in North Dakota and response of the market participants to this uneven demand-supply conditions.

5.3. Soybean Basis Model

Individual fixed effect estimates of the soybean basis model for Southeastern and Northeastern region are reported in the appendix (Table A3 & A4). Overall fixed effect estimates for both the regions are reported in Table 11 and Table 12 reports the significance tests of the effects. The variable *Premium Basis* is significant at 1% level for all the locations at Southeast region. For Northeast region, except Thompson Farmers and CHS Drayton, it is significant for all other locations at 1% and 5% level. Overall fixed effect estimates indicate that in comparison with a normal market, Southeastern and Northeastern soybean basis during a period of high local cash price compared to nearby futures price or low nearby futures price compared to local cash price, will be 140.23 cents and 95.17 cents stronger respectively, controlling for other independent variables.

Both Southeastern and Northeastern basis exhibit strong seasonality. A less expected result is that basis is significantly strong in fall (Sep-Nov) period (29 cents and 38 cents stronger than usual Southeastern and Northeastern basis level respectively) while significantly weak in winter (Dec-Feb) period (22 cents and 26 cents stronger compared to usual basis). Possible explanation for this is the export demand pattern of soybean. Figure 17 shows the weekly export sales of soybean. A close look at the graph gives us the answer to the question why at fall, ND soybean basis gets stronger, relative to the June – August time period. Historically soybean exports start building up during the fall period (Sep- Oct) and gradually decreases to the bottom at planting seasons or spring. Thus, increased external demand for soybean pushes the local cash price up. This is reason why there is a relatively larger and positive coefficient for the fall (Sep-Nov) dummy and smaller one for spring (Mar-May) and winter (Dec-Feb) dummy.

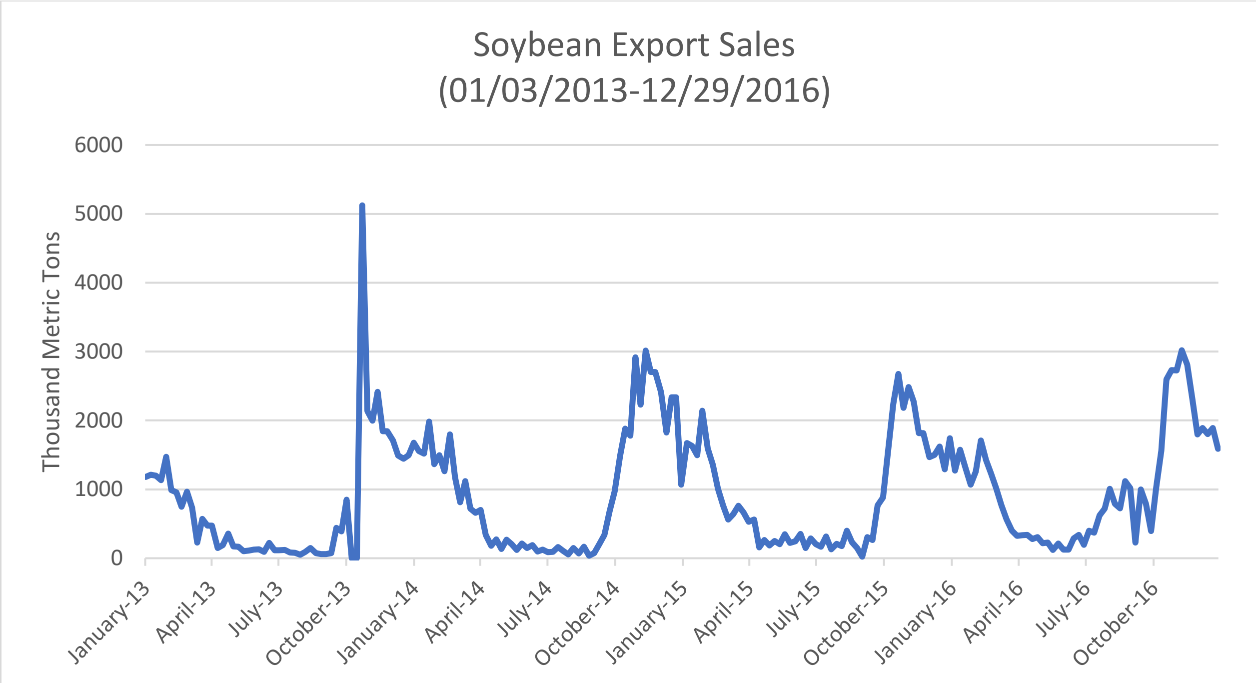

Figure 17. Weekly US Soybean Export Sales

Of the two export destination bids, PNW bid is highly significant for the regions studied. A marginal increase in PNW bid, strengthens local basis by 0.29 cents and 0.53 cents. This makes sense as 51% of the Southeastern region's soybean and 71% of the Northeast's soybean were shipped to PNW in 2015-1016 MY (UGPTI Publication No. 292).

Export sales and its lags have no significant effect on basis levels of the regions studied. The results allow for an assessment of the export demand from the point of view of elasticity debate. In this project, weeks have been used as the unit of observation. It is possible that, this short run or weekly adjustments in the local basis are not responsive to a change in weekly export sales. That is why the short run estimates indicate an inelastic relationship between export sales and soybean basis. Another likely explanation for this anomaly is that seasonal dummies are capturing most of the effects of export sales and its lags. As stated earlier, most of the exports were made during fall (Sep-Nov) season. Thus, it is highly likely that the magnitude of the effect of export sales and the lags on basis levels vary as a function of seasonal variables.

The sign of the primary rail service market (*ND Tariff FSC*) is consistent with a priori expectation and the coefficient is statistically significant for both regions. Fixed effect estimates indicate that one dollar increase (decrease) in the primary rail market bid will weaken (strengthen) local basis of Southeast and Northeast region by 0. 98 cents and 2.15 cents.

The regions studied differ in their response to secondary market bids. Southeast region's soybean basis is responsive to shuttle bids in deferred months (*Shuttle* T_1). Whereas Northeastern basis is sensitive to non-shuttle deferred bids (*Non-shuttle* T_1) and both current and deferred bids of shuttle rail service. This is expected because of the difference is these two regions destinations for soybean shipment. According to the UGPTI report (Publication No. 292), 31% of the total Northeastern soybean goes to markets other than recognized export terminals like PNW and Gulf whereas this "*other*" portion marks only 10% in the Southeastern soybean shipment. Soybean shipment from North Dakota to known export terminals is mainly made through shuttle train service. But shipment to other destination may be heavily comprised of single car, multi car and unit train services. This is the reason why non-shuttle bids are coming up as significant for Northeastern basis.

Carry in the futures market is significant for Southeast region only. With a marginal change in the price difference between two different contracts, Southeastern basis will weaken (strengthen) by 0.38 cents. change in the nearby futures prices is not statistically significant for any of the regions studied.

Table 11

Solution for Fixed Effects: Southeast and Northeast Region Soybean Panel Model Estimation

Effect	Soybean-Southeast	Soybean-Northeast
Intercept	15.5132	157.59*
Premium Basis	140.23***	95.16***
Sep-Nov	29.00***	38.0928***
Dec-Feb	22.12***	26.30***
Mar-May	4.75	1.11
Gulf Bid	0.080	-0.006
PNW Bid	0.2900***	0.5300***
Export	0.0008	0.0016
Export 1	-0.0022	-0.0014
Export 2	0.0002	0.0018
Export 3	0.0009	0.0008
ND Tariff FSC	-97.58***	-215.04***
Non-Shuttle T_0	0.0042	0.0089
Shuttle T_0	-0.0037	-0.0051*
Non-Shuttle T_1	-0.0047	-0.0114**
Shuttle T_1	-0.0091***	-0.0124***
Carry	-0.3842***	0.0886
NF Change	-0.0337	0.0782

Note: *, ** and *** indicate significance at 10%, 5% and 1% level respectively.

Table 12

Type 3 Test of Fixed Effects: Southeast and Northeast Region Soybean Panel Model Estimation

Effect	Soybean-Southeast	Soybean-Northeast
Premium Basis	99.83***	32.09***
Sep-Nov	16.32***	19.74***
Dec-Feb	7.76***	7.68***
Mar-May	0.78	0.03
Gulf Bid	0.57	0.00
PNW Bid	8.38***	19.94***
Export	0.04	0.12
Export 1	0.35	0.10
Export 2	0.00	0.14
Export 3	0.05	0.03
ND Tariff FSC	5.76**	19.60***
Non-Shuttle T_0	0.53	1.74
Shuttle T_0	2.33	3.13*
Non-Shuttle T_1	1.42	5.86**
Shuttle T_1	13.68***	17.59***
Carry	19.70***	0.73
NF Change	0.46	1.73

Note: *, ** and *** indicate significance of F value at 10%, 5% and 1% level respectively.

Table 13

Overall Fit Statistics for Soybean Basis Model

Fit Statistics	Southeast Soybean	Northeast Soybean
-2 Log Likelihood	7774.6	9245.6
AIC (Smaller is Better)	7816.6	9287.6
AICC (Smaller is Better)	7817.6	9288.6
BIC (Smaller is Better)	7812.2	9283.2

Fit statistic (Table 13) shows that Southeastern basis model is relatively a better fit compared to Northeastern basis model. Appendix Table A8 and A11 have been used to estimate intra-class coefficients in Table 14. It shows that temporal variation is dominant in the total basis volatility. But the magnitude of temporal coefficient is noticeably large (63%) for Southeast region.

Table 14

Soybean Intra-class Correlation Coefficient Estimation

Covariance Parameter	Intra-class Correlation Soybean- Southeast	Intra-class Correlation Soybean- Northeast
Elevator	7%	9%
Date	63%	24%
Residual	30%	68%

Bressler & King (1970) states that changes in prices through time reflect storage costs. Thus, shocks in storage incentives are likely to increase temporal price volatility. The analysis reveals that Southeastern soybean basis is significantly responsive to the carry in the futures market which is encouraging basis to move over time. Another probable explanation is that this region is an important source for local soybean supply. It is highly likely that the variability of local demand through time (specifically high export demand in harvesting seasons) and incentives from the futures contract months to hold grain are making temporal portion of the model high in scale. On the other hand, high residual in the Northeast soybean basis model is suggestive of low deterministic power of the model. Crop concentration is the main reason behind the difference between these two regions' covariance parameter estimate's explanatory power. Historically Southeast North Dakota is one of the top producer of soybean in the state. In 2015, it produced 64% more soybean than Northeast North Dakota (USDA, NASS). Since soybean is one of the most important crop of this region, responsiveness of the economic variables towards the basis levels is also high for this region. Therefore, only the inherent randomness of the predictors remains leftover for the error portion of the Southeast soybean basis model. Southeast North Dakota is also a heavy corn production area. Corn effect might play an important role behind the regional difference of residuals and basis volatility. Corn and soybean compete on several industries such as in the cooking oil industry, in the animal feed industry, in the biofuel industry etc. Therefore, the production/price of one does affect the volatility dynamics of another.

5.4. HRS Wheat Basis Model

Results from the HRS wheat basis model for both region are provided in Appendix Table A5 & A6. Both the models reflect seasonal pattern in HRS wheat basis. In North Dakota, hard red spring wheat is planted from April through late May and harvested in August to mid-September. Thus, HRS basis values are low during August and September, increase to reach a peak in November, decline into December, and then increasing to another peak in April compared to basis levels in other parts of a year. The results show very persistent positive seasonal variability (all three periods are significant at 1% level) in Southeastern basis compared to Northeastern basis (only fall basis is significant at 5% level). Positive coefficient indicates a strong cash market for hard red spring wheat which is backed by stable domestic demand for HRS wheat and strong foreign demand. The overall fixed effect estimates (Table 15) confirms that Southeastern basis is bottomed (6.71 cents more positive than usual basis) during September-November and peaked during December-February (9.96 cents more positive than normal basis). HRS wheat grows best in the northern areas of the state, and constant yield makes supply and demand more stable, which makes this region's basis seasonally less variable that its Southeastern counterparts.

North Dakota HRS wheat moves to domestic and export markets in both east and westbound shipments (Agricultural Shipment Brief, 2016). Portland, Oregon (PNW) and Minneapolis remained ahead of other destinations as a market for shipments of HRS wheat originating from North Dakota elevators. Thus, cash price that farmers receive from elevators is directly related with the price offered by wheat cash markets of Minneapolis (20-day delivery to arrive terminal bid) or Portland, Oregon 30-day delivery export bid. Analysis of this research also reveals the profound impact of these two markets price quotes. Both Minneapolis cash bids and Portland, Oregon quotes have significant positive impact on Southeast and Northeast region's HRS wheat basis. With every cent increase in Minneapolis bid and Portland, Oregon bid, Southeast HRS wheat basis strengthen by 0.37 cents and 0.11 cents respectively. Whereas, Northeastern basis strengthens by 0.26 cents and 0.24 cents respectively.

United States is one of the major exporter of hard red spring wheat, approximately half of the US HRS wheat are exported to foreign countries (USDA). So, exports play a very important role in ND HRS wheat basis. The analysis reveals that concurrent as well as lagged export sales volume has negative impact on both region's basis. Fixed effect estimates show that with every 1000 Metric ton increase in export sales, Southeastern HRS wheat basis weakens by 0.05 cents. As time approaches export sales effect gets less negative, for example, export sales laged two weeks weakens basis by 0.03 cents. Wheat supply-demand factors and seasonal market factors may be the reason why export sales are negatively affecting North Dakota HRS wheat basis level. Increased wheat supplies to the world market, an accumulation of wheat and feed grain supplies in ND grain elevators over last couple of years and weak export markets together have caused decline in HRS wheat price in many elevator locations.

According to Annual North Dakota Elevator Marketing Report, 2015-16 published by Upper Grain Plains Transportation Institute, rail is the dominant mode of transport for North Dakota wheat. *ND Tariff FSC* represents base price of freight rail service and fuel surcharges. It is significant at various significance level for most of the elevators at Southeastern and Northeastern location. The overall fixed effect estimates show that, with one dollar increase in primary rail service market cost, cash price of HRS wheat in Southeast and Northeast region decreases by 0.74 cents and 0.64 cents respectively.

None of the current month secondary rail bids for shuttle and non-shuttle rail service is significant for Southeastern elevators. But both shuttle and non-shuttle deferred delivery bids are significant at 1% and 5% level (Table 15) for this region. Overall Fixed effects estimates (Table 15) show that with a dollar increase in secondary market bids (*Non-Shuttle* T_1 and *Shuttle* T_1), Southeastern HRS wheat basis weakens by 0.4 cents and 0.5 cents respectively. For Northeastern region, only shuttle deferred delivery bids (*Shuttle* T_1) is significant at 1% level, where one dollar increase in this market's bid Northeastern cash price decreases by 0.7 cents (Table 15). Carry in the futures market significantly affects Southeastern basis but not Northeastern region's basis. Overall solutions for fixed effects (Table 15) shows that with one cent increase in the financial spread between two futures month, Southeastern HRS wheat cash price decreases by 0.21 cents. On the other hand, change in nearby futures price does not affect none of the region.

Table 15

Solution for Fixed Effects: Southeast and Northeast Region HRS Wheat Panel Model Estimation

Effect	Southeast HRS Wheat	Northeast HRS Wheat
Intercept	48.65	24.51
Sep-Nov	6.71***	6.23**
Dec-Feb	9.96***	3.46
Mar-May	8.69***	3.66
MPLS Bid	0.3747***	0.2642***
PNW Bid	0.1104***	0.2348***
Export	-0.0490***	-0.0604***
Export 1	-0.0325**	-0.0335**
Export 2	-0.0253*	-0.0315**
Export 3	-0.0054	-0.0153
ND Tariff FSC	-74.14***	-64.11**
Non-Shuttle T_0	-0.00007	0.00096
Shuttle T_0	-0.00078	-0.00154
Non-Shuttle T_1	-0.0037***	-0.0028
Shuttle T_1	-0.0049***	-0.0065***
Carry	-0.2058**	-0.0537
NF Change	0.0417	0.0379

Note: *, ** and *** indicate significance at 10%, 5% and 1% level respectively.

Table 16

Type 3 Test of Fixed Effects: Southeast and Northeast Region HRS Wheat Panel Model Estimation

Effect	Southeast HRS Wheat	Northeast HRS Wheat
Sep-Nov	9.95***	5.75**
Dec-Feb	18.34***	1.48
Mar-May	16.60***	1.96
MPLS Bid	60.28***	20.15***
PNW Bid	82.89***	251.05***
Export	12.30***	12.54***
Export 1	5.41**	3.85**
Export 2	3.23*	3.36*
Export 3	0.16	0.85
ND Tariff FSC	6.59**	3.29*
Non-Shuttle T_0	0.00	0.11
Shuttle T_0	0.61	1.57
Non-Shuttle T_1	5.93**	2.26
Shuttle T_1	24.59***	29.87***
Carry	4.26**	0.19
NF Change	1.26	0.70

Note: *, ** and *** indicate significance of F value at 10%, 5% and 1% level respectively.

Table 17

Overall Fit Statistics for HRS Wheat Basis Model

Fit Statistics	Southeast HRS Wheat	Northeast HRS Wheat
-2 Log Likelihood	6887.8	7544.8
AIC (Smaller is Better)	6927.8	7584.8
AICC (Smaller is Better)	6928.8	7585.7
BIC (Smaller is Better)	6923.7	7580.6

Table 18

HRS Wheat Intra-class Correlation Coefficient Estimation

Covariance Parameter	Intra-class Correlation Coefficient- Southeast	Intra-class Correlation Coefficient- Northeast
Elevator	25%	17%
Date	40%	36%
Residual	34%	47%

The fit statistics (Table 17) show that Southeastern basis model is marginally better in explaining HRS wheat basis volatility. The intra-class correlation coefficient (calculated from

Appendix Table A9 and A12) reported in the Table 18 shows that 25% and 17% of the total volatility in Southeastern and Northeastern HRS wheat basis is due to the difference across elevator locations (spatial variation). Time is the dominant source of volatility in both basis models. Compared to previous two commodities, delivery locations are significantly contributing to the HRS wheat basis volatility.

One possible explanation is that under a competitive market structure, basis in various locations respond to changes in local supply and demand, to changes in export demand and to changes in transfer cost (costs charged for primary and secondary rail services). Findings of our analysis support this idea. For example, Southeastern HRS Wheat basis levels are significantly responding to export terminal bids, export sales and rail service bids. Still temporal variation is high in HRS wheat basis model. Strong seasonality in the basis movement could be a potential economic explanation for the reported high temporal variation in both models. Seasonality in basis behavior can stem from both supply and demand side. During the study period (2013-2016), HRS wheat production in North Dakota was intensely volatile. In 2013, market was flooded with a record high production (319.2 million bushels) and in 2016 we have seen a sharp decline (18.63% less production compared to 2015) in ND's HRS wheat production. This suggests that main source of North Dakota's HRS wheat seasonality originates from the supply side.

CHAPTER 6. CONCLUSION

Corn, soybean and hard red spring wheat local basis behavior in Southeast and Northeast North Dakota were analyzed in this study. This chapter summarizes the findings of this study and discusses the scopes for the model improvement.

6.1. Concluding Remarks

Theoretically, storage, transportation, supply factors, domestic and foreign demand, industry consolidation, futures market carry and inversion, stockpiling, location and seasonality all contribute to basis volatility. The basis models defined in this research used some of these factors to provide a useful insight into the direction of basis volatility for corn, soybean and hard red spring wheat. Understanding basis volatility in terms of time and elevator location will allow grain merchandisers and producers to make better decisions regarding grain marketing and investment.

There are no previous studies which endeavored to estimate spatiotemporal volatility in commodity basis. This study is an attempt to fill that blank space. This is crucial in the sense that each of these levels (time and location) can introduce additional source of variability and correlation into the basis behavior of a region. This study employs maximum likelihood based mixed model procedure to quantify the variance of these two random effect parameters.

A separate model for each commodity in this study provide useful information about the variability of corn, soybean and HRS wheat basis and these models generally explain 50-80% of the variation in corn, soybean and HRS wheat basis. This study differs from the previous studies in the sense that none of the previous studies (i.e. Khal 1989, Karali et al. 2009, Streeter and Tomek 1992) focused on the simultaneous effect of time and elevator location on the basis volatility. The results of these basis models are generally consistent with previous studies with few interesting differences. The estimates of the predictor variables vary across seasons and locations.

Results of the volatility of corn, soybean and HRS wheat uncovered some significant differences in the effects of different predictors on basis volatility depending on the regions studied. For example, PNW bids have a significant impact on Northeast region's corn basis but not on Southeast region's basis, Non-Shuttle deferred bids has no significant effect on Southeast soybean basis but it significantly weakens Northeast soybean basis. This is indicative of sensitivity of a variable towards unique demand and supply scenario of different regions. It also suggests that grouping of commodity basis by delivery locations is a better method for studying regional basis volatility.

The effect of seasonal dummies on soybean and HRS wheat basis is significant. Positive coefficient during the fall (Sep-Nov) period is either indicative of a relatively strong cash market compared to nearby futures market or a weak futures market compared to local cash market. One way to decide between these two situations is to look at the impact of futures carry on the local basis levels. For example, Southeastern HRS wheat basis weakens as export sales and carry increase marginally. Positive carry is the financial incentive to store grain. Thus, weak basis and wide carry of Southeast region is signaling farmers/grain elevators that storing grain is likely to render positive return. This may be an indication of a strong and more responsive HRSW futures market towards the economic variables that are being used in this study compared to the local cash market for HRSW.

Analysis of this research can give an important insight regarding how export terminal basis and export sales can contribute to the local basis volatility. Analysis shows that destination bids have significant impact on HRS wheat and soybean basis volatility. This is consistent with the prior study by Manfredo & Sanders (2006). But the models differ in measuring the effect of export sales on local basis. Although more than 85% of total HRS wheat and 90% of the total soybean of these regions are shipped out of state only HRS wheat basis is significantly affected by export sales and its lags.[7] One possible explanation for this relationship is that there is significant difference in local demand for these two commodities. During the study period (2012-2016), average yearly demand from the local processors of North Dakota for hard red spring wheat and soybean were 26% and 9.75% respectively[8]. If basis is viewed as the cost of storing a commodity or market specific price of a location, then it's a good representation of local demand and supply. Thus, any surge in local demand should be reflected by local basis. HRS wheat basis used in this analysis is capturing this relatively large local demand shocks and injecting more spatial influence in basis volatility model. That is why, random effects of elevator locations on the unobserved HRS wheat basis determinants (the error term) is higher (21% and 8% respectively for HRS wheat and soybean) than that of soybean.

Southeastern corn basis model is another example of how relatively large local demand can absorb the shocks in the export terminals basis. During the study period (2012-2016), yearly average of southeastern corn shipped to the local market was 37%, for Northeastern region this was only 6%. Although during that period, a significant amount of Southeastern and Northeastern corn (on average 32.75% and 31.25% respectively) were shipped to PNW each year, still PNW bids are not significant for Southeastern basis.[9]

Bressler and King (1970) states that efficient market will establish prices that are interrelated through space by transportation costs and through time by storage costs. Although

[7] See UGPTI publication No. 292 at http://www.ugpti.org/resources/reports/downloads/dp-292.pdf
[8] See UGPTI publication No. 292, 287, 278 and 268 at http://www.ugpti.org/resources/reports
[9] See UGPTI publication No. 292 287, 278 and 268 at http://www.ugpti.org/resources/reports

this assertion is a simplification of real market and price scenario, temporal and special distortion in basis pricing performance in any pricing model can be spotted through incorporating the variables used in this analysis. In this analysis, secondary and primary rail service bids have been used to capture unobserved spatial variation between regional markets and the terminal markets; carry in the futures contracts price and change in nearby futures price have been used to capture unobserved temporal variation in the local basis levels.

Most of the variables used in this research were significant at various levels. Combined results indicate that for all three commodities, random effect of time is dominant in explaining local basis volatility. This is because of the highly seasonal production of all three commodities. Difference in the magnitude of temporal variation may be due to the difference in storage costs across different market locations for different commodities.

However, this research is an extension to the current basis literature in a sense that it endeavors to analyze unobserved basis determinants stemming from the variable effect of time at different elevator locations. This study may help farmers and extension economists to better understand the temporally and spatially defined effect of known exogenous parameters on corn, soybean and hard red spring wheat volatility. Basis volatility pattern and factors affecting basis revealed in this study can also help industry professionals to better understand and manage local basis levels. Undoubtedly, basis volatility has impact on marketing, production and investment decisions. The higher the volatility, the higher will be the cost of managing the risks associated with these activities. Thus, accurate and meaningful interpretation of basis volatility is extremely important in developing effective risk management strategies, creating marketing plan and taking investment decisions.

6.2. Recommendation

This study can be considered as an initial research into agricultural commodity basis volatility across time and delivery location. There are ample opportunities for model improvement.

One limitation of the estimated basis model is the effect of an inverted market on basis volatility. This is particularly important if we want to test whether strong basis levels are associated with strong local demand. This study has not included any variable that directly measures the effect of supply and demand of corn, soybean and hard red spring wheat on local basis levels. Hence, future researches could include local, domestic and world agricultural commodity supply and demand factors to measure the degree to which these factors explain local basis volatility.

Only two crop districts, out of nine total districts, in North Dakota (Northeast and Southeast) were considered for this study. Thus, an extensive inspection of the current basis model to cluster basis volatility around time and elevator location for other crop districts is recommended. Furthermore, a wide time period with less missing data points should be chosen. Current model includes 209 trading days (4 year) which may not enough to study volatility dynamics comprehensively.

The basis behavior model defined in this research indicates that several of the included predictors are significant in defining basis volatility in terms of time and market. However, another direction for future research is testing cost of carry model. This can be done through including variables like insurance cost and interest rate. This will allow us to test whether gains from storing grain over time can cancel out physical and opportunity costs of storing grain.

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APPENDIX

Table A1

Corn Fixed Effect Estimate- Southeast Region

Variables	Arthur companies	Alton Grain Alton	Central City Grain	Finley Farmers	Dakota Ag. Cooperatives	Full Circle Ag
Intercept	53.23*	22.04	131.70***	118.90***	54.52*	77.34***
Premium Basis	76.76***	72.90***	85.97***	43.44***	87.53***	78.90***
Sep-Nov	-4.00	-5.97	-8.54**	-6.66	-4.02	-13.70***
Dec-Feb	-1.59	-1.74	-2.08	1.10	0.0200	-7.94**
Mar-May	-4.14	-6.00**	-4.48	-4.58	-7.11**	-7.87***
Gulf Bid	0.1200	0.1900**	-0.1400	0.2400*	0.1000	-0.0300
PNW Bid	0.0708	0.00015	0.2215***	-0.0674	-0.0312	0.1509**
Export	-0.0047	-0.0053	-0.0066	-0.0064	-0.0069	-0.0053
Export 1	-0.0086**	-0.0072***	-0.0120**	-0.0097	-0.0079*	-0.0105***
Export 2	-0.0087**	-0.0092**	-0.0025	-0.0078	-0.0079*	-0.0094***
Export 3	-0.0094**	-0.0092**	-0.0061	-0.0101	-0.0074	-0.0099***
ND Tariff FSC	-72.46***	-47.38**	-141.39***	-119.18***	-62.19***	-86.089***
Non-Shuttle T_0	-0.0011	-0.00006	-0.00006	-0.0018	-0.0007	0.0013
Shuttle T_0	-0.0013	-0.0021	-0.0017	-0.00013	-0.0022	-0.0020
Non-Shuttle T_1	-0.0028	-0.0027	-0.0022	-0.003	-0.0033	-0.0026
Shuttle T_1	-0.0037***	-0.0032**	-0.0041***	-0.0028	-0.0023	-0.0019
Carry	-0.3213***	-0.3606***	-0.3907***	-0.4281***	-0.3453***	-0.2284***
NF Change	-0.1193**	-0.1359**	-0.0604	-0.1384	-0.0521	-0.0222

Note: *, ** and *** indicate significance at 10%, 5% and 1% level respectively.

Table A2

Corn Fixed Effect Estimate- Northeast Region

Variables	BTR	Thompson Farmers	CHS Drayton	Equity Coop	Osnabrock farmers	Northwood Farmers
Intercept	249.05***	149.15***	217.47***	88.67**	333.35***	81.44***
Premium Basis	10.37	-0.6376	19.50***	83.12***	40.69***	68.36***
Sep-Nov	12.58*	-1.18	-2.99	-6.81	-6.59	-6.37
Dec-Feb	11.97*	4.00	-0.2904	3.00	-7.42	-7.10*
Mar-May	-2.08	-1.31	-0.086	-5.65	-12.51***	-4.047
Gulf Bid	0.1652	0.1634	0.3000***	-0.0375	-0.3455**	-0.0608
PNW Bid	0.3873***	0.5616***	0.4318***	0.2213**	0.3969***	0.2345***
Export	-0.0006	-0.0074	-0.0014	-0.0063	-0.0055	-0.0055
Export 1	-0.0064	-0.0077	-0.0047	-0.0090*	-0.0102*	-0.0076*
Export 2	-0.0028	-0.0062	-0.0041	-0.0068	-0.0163**	-0.0088**
Export 3	-0.0076	-0.0084*	-0.0056	-0.0058	-0.0135**	-0.0094**
ND Tariff FSC	-275.82***	-199.79***	-252.43***	-113.06***	-295.92***	-107.86***
Non-Shuttle T_0	0.0003	-0.0013	-0.0037	-0.0014	-0.00098	-0.00046
Shuttle T_0	-0.00015	-0.00225	-0.00090	-0.00122	0.00022	-0.00058
Non-Shuttle T_1	0.00159	-0.00236	-0.00128	-0.00328	0.00225	-0.00303
Shuttle T_1	-0.01065***	-0.00638***	-0.00581***	-0.00483***	-0.00438**	-0.00357***
Carry	-0.3084**	-0.02455	-0.1606**	-0.3212***	-0.5066***	-0.2077***
NF Change	0.00451	0.08930	0.12210*	-0.09770	-0.30470***	-0.12770**

Note: *, ** and *** indicate significance at 10%, 5% and 1% level respectively.

Table A3

Soybean Fixed Effect Estimate- Southeast Region

Soybean	Arthur companies	Alton Grain	Central City Grain	Finley Farmers	Dakota Ag. Cooperatives	Full Circle Ag
Intercept	-17.19	-1.13	76.57	116.67**	-57.07	-39.89
Premium Basis	132.84***	124.34***	144.67***	144.55***	173.12***	170.73***
Sep-Nov	30.00***	34.63***	29.15***	47.63***	13.71**	21.61***
Dec-Feb	18.41*	27.95***	20.68**	37.61***	8.94	20.46***
Mar-May	0.2024	7.56	-1.86	14.06**	-3.16	12.60***
Gulf Bid	-0.1169	0.1693	-0.040	0.2776**	-0.0946	0.2540***
PNW Bid	0.3935***	0.2363**	0.4329***	0.1372	0.5226***	0.03727
Export	0.0014	0.0009	0.0013	0.0011	-0.0011	0.0001
Export 1	-0.0020	-0.0027	-0.0026	-0.0028	-0.0026	-0.0019
Export 2	-0.0023	0.0007	-0.0009	0.0002	0.0003	0.0025
Export 3	0.0033	0.0002	0.0017	0.0004	0.0011	-0.0014
ND Tariff FSC	-71.40	-89.34**	-144.55***	-173.61***	-45.37	-52.47
Non-Shuttle T_0	0.0065	0.0005	0.0047	0.0066	0.0007	0.0050
Shuttle T_0	-0.0027	-0.0046*	-0.0028	-0.0042	-0.0048**	-0.0032
Non-Shuttle T_1	0.0031	-0.0049	-0.0074*	-0.0085*	-0.0037	-0.0067*
Shuttle T_1	-0.0166***	-0.0064**	-0.0096***	-0.0080***	-0.0099***	-0.0045
Carry	-0.4368***	-0.4821***	-0.2868***	-0.3678***	-0.3095***	-0.3113***
NF Change	-0.0669	-0.0356	-0.0573	0.0055	-0.0817*	-0.0168

Note: *, ** and *** indicate significance at 10%, 5% and 1% level respectively.

Table A4

Soybean Fixed Effect Estimate- Northeast Region

Variables	BTR Leeds	Thompson Farmers	CHS Drayton	Equity Coop	Osnabrock farmers	Northwood Farmers
Intercept	177.65**	21.51	370.47***	21.66	236.25**	133.34**
Premium Basis	42.80**	-30.90	30.32	164.90***	139.84***	187.23***
Sep-Nov	39.35***	35.03***	43.86***	37.15***	42.65***	31.06***
Dec-Feb	35.27***	21.80*	24.28	29.22***	22.89*	25.77***
Mar-May	11.93	1.54	-14.41	11.17**	-2.48	3.53
Gulf Bid	-0.1100	-0.3000*	0.3342	-0.0168	0.1386	0.2288**
PNW Bid	0.6781***	0.7936***	0.5843**	0.3470***	0.3093**	0.2705**
Export	0.0039	0.0017	0.0044	0.0003	-0.0023	-0.0001
Export 1	-0.00003	-0.0036	0.0019	-0.0021	-0.0045	-0.0006
Export 2	0.0007	0.0010	0.0059	0.0014	0.0015	0.0017
Export 3	0.00133	0.00089	0.00136	-0.00050	0.00291	-0.00015
ND Tariff FSC	-239.32***	-126.26**	-382.67***	-112.98***	-250.06***	-193.76***
Non-Shuttle T_0	0.0081	0.0124	0.0171	0.0049	0.0029	0.0025
Shuttle T_0	-0.0067*	-0.0077**	-0.0071	-0.0032	-0.0017	-0.0025
Non-Shuttle T_1	-0.0043	-0.0009	-0.0305***	-0.0102**	-0.0150**	-0.0094**
Shuttle T_1	-0.0122***	-0.0177***	-0.0188***	-0.0087***	-0.0049	-0.0074***
Carry	0.2823**	0.4004***	0.3820**	-0.1996**	-0.3096**	-0.1519
NF Change	0.1590**	0.1451*	0.2496**	-0.02303	-0.0652	0.0106

Note: *, ** and *** indicate significance at 10%, 5% and 1% level respectively.

Table A5

HRS Wheat Fixed Effect Estimate- Southeast Region

HRS Wheat	Arthur companies	Alton Grain	Central City Grain	Finley Farmers	Dakota Ag. Cooperatives	Full Circle Ag
Intercept	85.52*	27.19	28.59	152.49***	-3.07	-0.6729
Sep-Nov	3.49	10.54***	9.59***	9.11***	8.45***	-1.62
Dec-Feb	8.00***	6.57***	8.49***	11.53***	13.88***	10.99***
Mar-May	7.29***	6.76***	4.86*	12.48***	11.06***	8.73***
MPLS Bid	0.3858***	0.3169***	0.4699***	0.2167***	0.4912***	0.3354***
PNW Bid	0.0885***	0.1991***	0.1604***	0.1076***	0.0509***	0.0616***
Export	-0.0462***	-0.0737***	-0.0423**	-0.0658***	-0.0379***	-0.0307***
Export 1	-0.0312**	-0.0368**	-0.0269	-0.0401**	-0.0319**	-0.0313***
Export 2	-0.0275**	-0.0204	-0.0183	-0.0409**	-0.0134	-0.0184
Export 3	-0.0035	-0.0208	-0.0007	0.0066	-0.0045	0.0025
ND Tariff FSC	-101.22***	-57.194*	-73.19*	-134.89***	-38.17	-40.41
Non-Shuttle T_0	-0.0014	0.0041	-0.0012	-0.0004	-0.0008	-0.0001
Shuttle T_0	-0.0004	-0.0024	-0.0007	-0.0007	-0.0003	-0.0002
Non-Shuttle T_1	-0.0042***	-0.0033*	-0.0057***	-0.0035*	-0.0021	-0.0051***
Shuttle T_1	-0.0041***	-0.0038***	-0.0072***	-0.0068***	-0.0034***	-0.0013
Carry	-0.2552***	-0.2120*	-0.0503	-0.4968***	-0.1603*	-0.0677
NF Change	0.0323	0.0539	0.0509	0.0271	0.0145	0.0778***

Note: *, ** and *** indicate significance at 10%, 5% and 1% level respectively.

Table A6

HRS Wheat Fixed Effect Estimate- Northeast Region

HRS Wheat	BTR Leeds	Thompson Farmers	CHS Drayton	Equity Coop	Osnabrock farmers	Northwood Farmers
Intercept	101.45	-41.15	-103.45	72.78	-52.76	146.64**
Sep-Nov	7.96**	4.43	8.56***	3.93	8.28***	4.01
Dec-Feb	5.53	2.21	3.77	4.07	-3.01	8.09**
Mar-May	-1.37	6.83**	9.49***	-1.52	-1.02	10.16***
MPLS Bid	0.3095***	0.2688***	0.3346***	0.4756***	0.04284	0.1328*
PNW Bid	0.2140***	0.2296***	0.2445***	0.1935***	0.3366***	0.1914***
Export	-0.0481**	-0.0735***	-0.0672***	-0.0419**	-0.0809***	-0.0527**
Export 1	-0.0357	-0.0411**	-0.0364*	-0.0297*	-0.0141	-0.0423**
Export 2	-0.0448**	-0.0369*	-0.0329	-0.0140	-0.0216	-0.0371*
Export 3	-0.0210	-0.0143	-0.0155	-0.0004	-0.0194	-0.0233
ND Tariff FSC	-116.90**	-16.50	20.78	-104.00***	-13.07	-138.95***
Non-Shuttle T_0	-0.0031	0.0005	0.0003	-0.0002	0.0062*	0.0014
Shuttle T_0	0.0004	-0.0022	-0.0020	-0.00003	-0.0028*	-0.0025*
Non-Shuttle T_1	-0.0040*	-0.0058***	-0.0019	-0.0039**	-0.0007	-0.0001
Shuttle T_1	-0.0080***	-0.0042***	-0.0067***	-0.0069***	-0.0066***	-0.0064***
Carry	0.1050	-0.0567	0.1309	-0.0395	-0.2947**	-0.2402
NF Change	0.0893	-0.0544	-0.0079	0.0930**	-0.0069	0.0985*

Note: *, ** and *** indicate significance at 10%, 5% and 1% level respectively.

Table A7

Covariance Parameter Estimates- Southeast Corn

Covariance Parameter Estimates							
Cov Parm	Estimate	Standard Error	Z Value	Pr > Z	Alpha	Lower	Upper
Elevator	27.0945	15.9033	1.70	0.0442	0.05	11.1244	136.27
Date	146.67	17.6553	8.31	<.0001	0.05	117.40	188.50
Residual	60.6716	3.1020	19.56	<.0001	0.05	55.0228	67.2419

Table A8

Covariance Parameter Estimates- Southeast Soybean

Covariance Parameter Estimates							
Cov Parm	Estimate	Standard Error	Z Value	Pr > Z	Alpha	Lower	Upper
Elevator	43.8771	26.2478	1.67	0.0473	0.05	17.7801	230.45
Date	418.80	51.6386	8.11	<.0001	0.05	333.51	541.76
Residual	198.04	10.2642	19.29	<.0001	0.05	179.37	219.81

Table A9

Covariance Parameter Estimates- Southeast Hard Red Spring Wheat

Covariance Parameter Estimates							
Cov Parm	Estimate	Standard Error	Z Value	Pr > Z	Alpha	Lower	Upper
Elevator	43.2098	25.1703	1.72	0.0430	0.05	17.8337	213.67
Date	68.6735	8.8076	7.80	<.0001	0.05	54.2199	89.8221
Residual	58.6496	2.9714	19.74	<.0001	0.05	53.2352	64.9387

Table A10

Covariance Parameter Estimate- Northeast Corn

Covariance Parameter Estimates							
Cov Parm	Estimate	Standard Error	Z Value	Pr > Z	Alpha	Lower	Upper
Elevator	41.4438	24.7944	1.67	0.0473	0.05	16.7930	217.71
Date	100.59	15.8079	6.36	<.0001	0.05	75.5965	140.49
Residual	232.47	11.7636	19.76	<.0001	0.05	211.03	257.37

Table A11

Covariance Parameter Estimates- Northeast Soybean

Covariance Parameter Estimates							
Cov Parm	Estimate	Standard Error	Z Value	Pr > Z	Alpha	Lower	Upper
Elevator	165.20	100.19	1.65	0.0496	0.05	66.3041	896.15
Date	432.63	74.8271	5.78	<.0001	0.05	316.62	626.85
Residual	1242.23	64.2774	19.33	<.0001	0.05	1125.29	1378.51

Table A12

Covariance Parameter Estimates- Northeast Hard Red Spring Wheat

Covariance Parameter Estimates							
Cov Parm	Estimate	Standard Error	Z Value	Pr > Z	Alpha	Lower	Upper
Elevator	40.5098	23.8040	1.70	0.0444	0.05	16.6197	204.25
Date	87.0889	11.8659	7.34	<.0001	0.05	67.8172	115.97
Residual	111.62	5.6058	19.91	<.0001	0.05	101.40	123.48