The probability of nonconvergence and its spatial effects in the hard red winter wheat market

by

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Abstract

Nonconvergence in commodity markets has caused some market participants to question the effectiveness of using futures contracts to effectively set prices. This failure of the price discovery function of the futures market increases a farmer's basis risk exposure when hedging their grain. A variable storage rate (VSR) mechanism was adopted in 2018 for the hard red winter (HRW) wheat market to prevent nonconvergence. The VSR adjusts the storage rate on delivery instruments dependent upon the amount of financial full carry present in the market. This thesis will examine the efficacy of the VSR and show the spatial effects of nonconvergence in the HRW wheat market throughout the state of Kansas.

A dataset consisting of daily spot prices at 91 grain handling facilities across Kansas, daily closing futures prices, and daily three-month London Interbank Offered Rate from 2004 to 2019 was used in the analysis.

To determine the effectiveness of the VSR on preventing nonconvergence, each contract month was categorized into three convergence outcomes based on the average basis during the delivery period for four facilities in three delivery locations in Kansas. A multinomial model was used to determine the probability of each convergence outcome given an average percent financial full carry in the observation period. The occurrence of nonconvergence was found to be significantly more probable in all locations when the average percent financial full carry in the observation period is greater than 80%, supporting the underlying theory behind the adoption of the VSR.

Next, basis at 90 grain elevators across Kansas was predicted using a naïve pricing model with respect to basis in Kansas City, a delivery location, to determine the effect of nonconvergence on basis at outlying locations. Results indicate the presence of nonconvergence

at delivery location has a significant effect on basis at some, but not all, locations. Locations with a higher grain storage capacity are less likely to be affected by nonconvergence, lending support to the theory that nonconvergence can be caused by low storage availability.

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Chapter 1 - Introduction

Recent bouts of nonconvergence in agricultural commodity markets have raised concerns regarding the effectiveness of futures contracts. Nonconvergence occurs when cash prices diverge from the underlying futures contract more than anticipated during the delivery period. Traders expect the futures price and the cash price at a contract specified delivery location to trend towards and meet one another as the futures contract matures due to the threats of arbitrage and delivering against the contract.

Nonconvergence results in wider-than-expected basis, the difference between the cash price and futures price, and increased basis risk exposure to market participants. Moreover, nonconvergence causes a failure of the price discovery function of the futures market as the futures price no longer represents the value of the underlying commodity. This failure could disincentivize users from using the futures market to hedge, leading to a reduction in liquidity and could worsen the failure of the price discovery function.

In 2017, the Chicago Board of Trade (CBOT) introduced a variable storage rate (VSR) mechanism in the hard red winter (HRW) wheat contract in an effort to prevent nonconvergence. The VSR incrementally adjusts the storage rate of shipping certificates and is triggered by the percent financial full carry, a ratio of the nearby spread over the cost of storing a shipping certificate into the next delivery period.

This thesis will examine nonconvergence in the HRW wheat contract throughout the state of Kansas in two parts. The first will discover the relationship between percent financial full carry and nonconvergence to determine the merit of the variable storage rate (VSR) as a preventative measure. The second will find spatial patterns in the effects of nonconvergence on basis in non-delivery locations to determine if there is a heterogeneous spatial effect of nonconvergence throughout the state.

The purpose of this thesis is to determine if the VSR will be an effective tool in preventing nonconvergence and to help farmers and elevator managers understand the causes and effects of nonconvergence in order to make informed marketing decisions in a volatile marketplace.

Chapter 2 - Literature Review

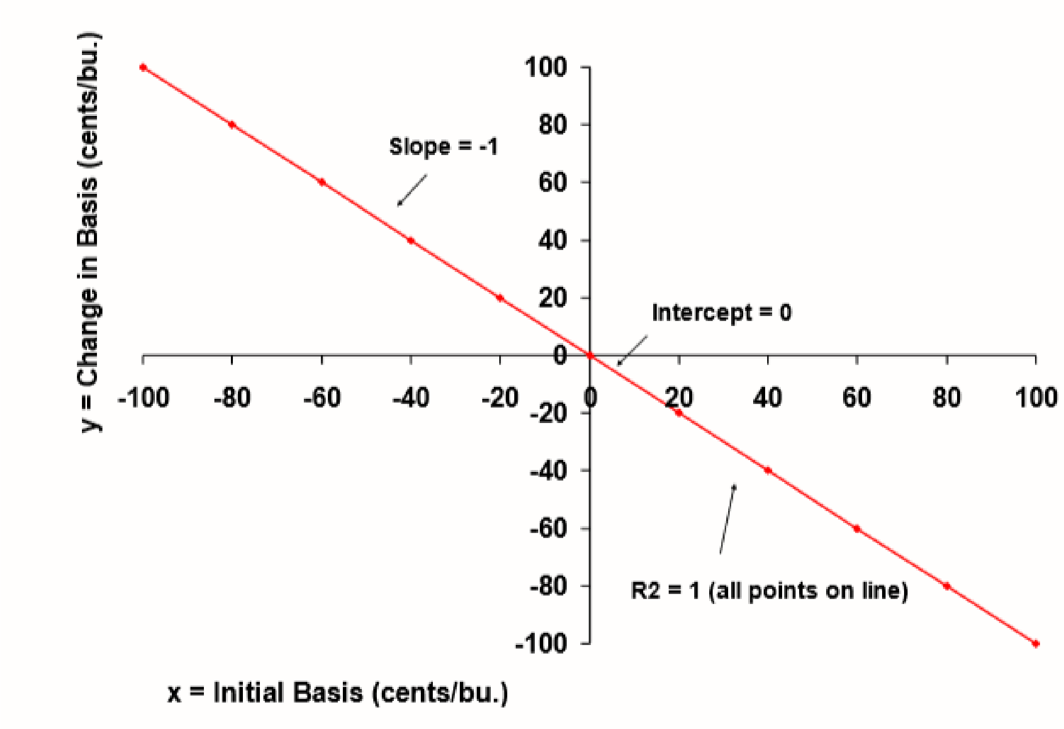
2.1 Overview

Futures markets are a central fixture in agricultural commodity marketing. Adjemian, Garcia, Irwin, and Smith (2013) discuss price discovery, risk management opportunities, and a source of storage signals as core functions of futures markets. Arguably the most important task for the futures market is price discovery of the underlying commodity. As market participants buy and sell futures contracts, a consensus price of the good for a specific date in the future is determined. The local spot price is derived from this consensus price and accounts for various factors. For the typical sale of physical grain, the cash price farmers receive will be equal to the current price of the nearby contract plus basis, the difference between the cash and futures price. Basis allows the cash price to include the value of the commodity plus local supply and demand factors. The threat of arbitrage, or hauling the grain to another location, forces the local cash price to be equal to the price at a location with higher demand minus the transportation cost and other transaction costs. When nonconvergence is present, the cash price of the commodity diverges significantly from the price of futures contracts during the delivery period. Adjemian et al. (2013) argue that nonconvergence causes the price discovery function of the futures market to fail as the futures price no longer accurately represents the actual price of the commodity.

Producers and consumers of commodities use futures contracts and options to manage price risk by offsetting their cash position with an opposite futures position, known as hedging. When futures markets are working properly, the expected net price of the commodity is equal to the futures price when the hedge was initiated plus expected basis. This effectively locks in a price for the commodity. Adjemian et al. (2013) explain that when nonconvergence is present, the value of the hedge is diminished because basis is no longer predictable, resulting in a higher risk premium due to a reduction in the probability of attaining the expected net price. The authors concede that a hedge would still protect the user from price risk if the cash and futures prices trend together perfectly.

Perfect predictability of basis helps to explain how futures markets produce storage signals. Basis varies by location and accounts for local supply and demand shifters as well as transportation costs to the nearest load-out facility due to arbitrage. Irwin, Garcia, Good, and Kunda (2008) explain that in a well-functioning futures market, basis is perfectly predictable at delivery points. At any given time, the difference between the cash price and the futures price should represent the cost of storing the grain until the expiration of the nearby contract (Adjemian et al., 2013). Therefore, basis should be weakest immediately following the expiration of the previous contract. When basis is predictable, holders of physical grain will store the grain if basis is weak with the expectation that basis will rise to par value at the contract's expiration (Irwin et al., 2008). Figure 2.1, from Irwin et al. (2008), illustrates perfect predictability of basis at delivery locations. For example, if basis is initially 60 cents under, it would be expected to increase 60 cents before the delivery period begins. During nonconvergence, basis becomes unpredictable. The increased basis risk exposure from this unpredictability could drive away producers and consumers of the commodity who wish to use the futures for risk mitigation through hedging, resulting in decreased liquidity. In extreme cases, low liquidity as a result of nonconvergence could lead to a closure of the futures contract. As these users leave the trading pool, speculative traders, or traders who are not connected to the production or consumption of the commodity, could become the driving force in determining the consensus price. This could lead to a growing disconnect between the cash and futures prices.

Figure 2.1 Perfect Basis Predictability



Source: Irwin et al. (2008).

Another storage signal produced by the futures market comes from the nearby spread. If the difference in price between the nearby and deferred contract is greater than the cost to store the grain, owners of the physical commodity will be incentivized to store the grain with the expectation of a better price for the commodity in the future.

2.2 The Delivery Period

An understanding of the delivery process for the HRW wheat contract is needed to explain a potential source of nonconvergence. Detailed delivery instructions can be found in Chapter 7 of the Chicago Board of Trade's (CBOT) rulebook with HRW wheat specific information in Chapter 14H (CME Group, 2019a; CME Group, 2019b). An informative video called "Understanding the Grain Delivery Process" can also be found on the CME Institute's website (CME Group, 2016).

Grain handling facilities must meet the requirements laid out in rule 703 of the CBOT Rulebook in order to become a regular facility (CME Group, 2019a). Most notably, they must have at least 100,000 bushel storage capacity, be connected to a railway, and have the ability to load at least 30 train cars per day. An Excel document showing all of the regular firms can be found at the end of Chapter 7 of the CBOT rulebook (CME Group, 2019a). The regular firms in the HRW wheat contract are located within the switching limits of Kansas City, Hutchinson, Salina/Abilene, and Wichita. Only regular facilities can create new delivery instruments; however, as Irwin, Garcia, Good, & Kunda (2011) explain, if other shorts are holding a delivery instrument, either through purchasing an outstanding delivery instrument or from being delivered upon previously, they can also initiate the delivery process.

The delivery period for each contract occurs from the 1st to the 15th of the delivery month. For example, the delivery period for the May '19 contract will occur from May 1, 2019 to May 15, 2019. Delivery against a HRW wheat contract is done with a delivery instrument in lieu of the physical grain. Delivery instruments used in CBOT contracts are warehouse receipts and shipping certificates. Warehouse receipts give ownership of the contract specified quantity (5000 bu/contract) and quality of grain to the holder of the receipt and requires the grain to be stored in the regular facility that issued the receipt. Moreover, regular facilities cannot issue warehouse receipts unless they have the grain in storage, limiting the number of outstanding warehouse receipts to the storage capacity of regular facilities. Prior to the March '18 contract, warehouse receipts were the utilized delivery instrument for the HRW wheat contract.

Beginning with the March '18 contract, the CBOT made significant changes to the HRW wheat contract including the switch from warehouse receipts to shipping certificates. The amendments to the HRW wheat contract can be found in the CME Group's Special Executive

Report 7923 (CME Group, 2017b). As Garcia, Irwin, and Smith (2014) explain, shipping certificates allow the regular facility a higher level of flexibility with their physical storage because, unlike warehouse receipts, they do not require the issuing regular facility to maintain the grain in storage. However, if the holder of the shipping certificate demands load-out, the regular facility that issued the shipping certificate must source the grain and begin load out within three business days (Irwin et al., 2011). Moreover, the number of outstanding shipping certificates is not limited by the storage capacity of the regular facility that issued the shipping certificate.

The load-out process converts delivery instruments into physical grain and is the link between futures and cash prices. When a long demands load-out, the regular facility that issued their delivery instrument mixes, grades and loads the grain according to the long’s instructions. As Irwin et al. (2011) explain, when the long converts their delivery instrument into physical grain, they inflate demand in the cash market and raise the cash price.

There are costs associated with the load-out process that may incentivize the long to store the delivery instrument rather than going through the load-out process. The long pays a load-out fee to cover the costs of load-out to the regular facility and is responsible for the transportation of the grain after the load-out process. The costs of load-out contribute to the costs of delivery against the futures contract. Irwin et al. (2011) estimate the cost of delivery to be 8 cents per bushel for all CBOT contracts based on a 6 cent barge load-out fee and a 2 cent fee for other costs including grading and blending the grain.

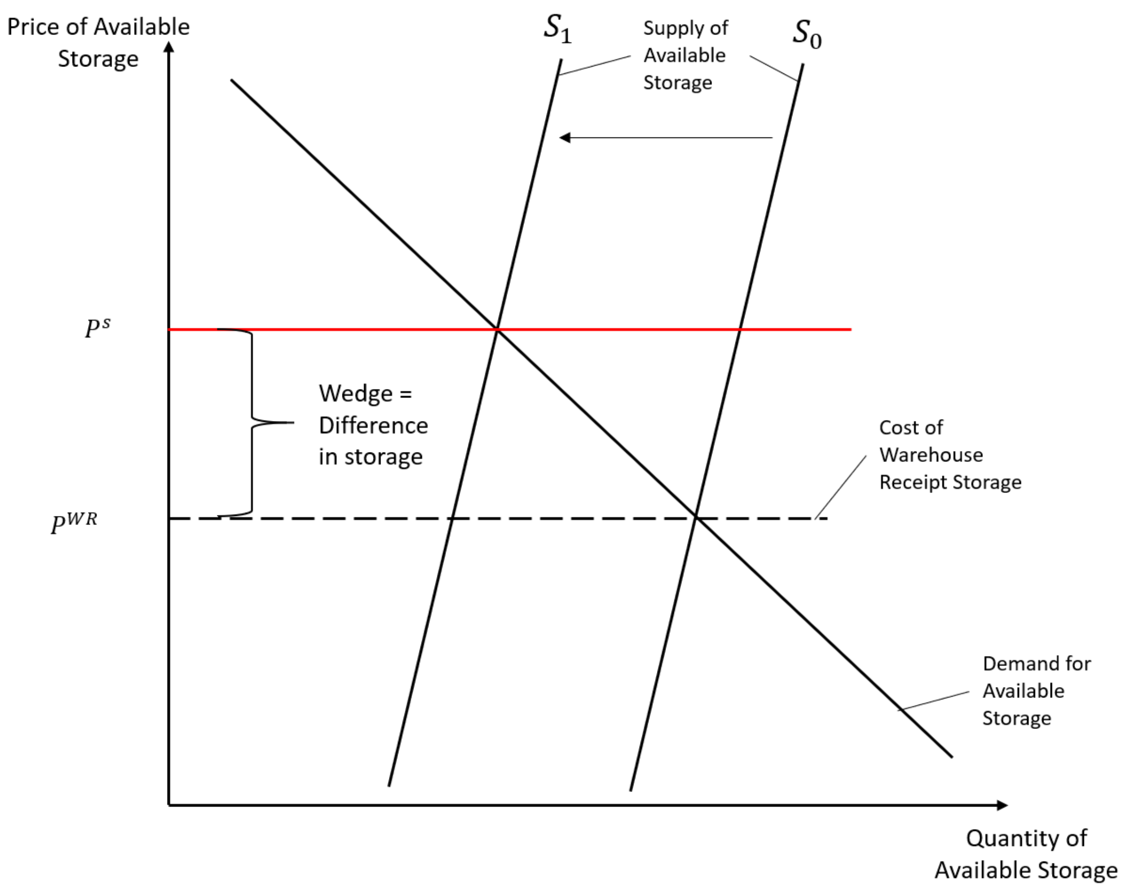
2.3 Storage Rates

Adjemian et al. (2013) attribute the lack of convergence in grain futures markets to the disconnect between storage rates for the physical commodity and the storage rates for the delivery instrument specified in the commodity's contract. Delivery instruments can be held indefinitely if daily storage fees are paid in accordance to rule 14H08 (CME Group, 2019b). Prior to the September '11 contract, the Kansas City Board of Trade (KCBT), now owned by the parent company of the CBOT, set the storage rate on warehouse receipts at $0.00148/bu/day (approximately 4.5¢/bu/month) for all contract months. Following a period of nonconvergence, the KCBT implemented a seasonal storage rate with a higher storage rate for the July and September contracts to account for the increased demand for storage of physical grain in the months following harvest, effective with the September '11 contract. The seasonal rates for the July and September contracts were set at $0.00296/bu/day (approximately 9¢/bu/month) while the other contract months' storage rates were increased to $0.00197/bu/day (approximately 6¢/bu/month). The seasonal storage rates stayed in effect until a variable storage rate (VSR) mechanism was introduced in the HRW wheat contract for the March-May '18 contract spread, explained in detail in the CME Group's Special Executive Report 7872 (CME Group, 2017a). The VSR will trigger an increase of $0.0010/bu/day (approximately 3¢/bu/month) to the storage rate of shipping certificates if the average percent financial full carry during the observation period is greater than 80%, a decrease of $0.0010/bu/day to the storage rate if the average percent financial full carry during the observation period is less than 50%, or no change to the current storage rate if the average percent financial full carry during the observation period is between 50% and 80%. The observation period runs from the 19th day of the previously expired contract month to the expiration of the nearby contract's options. For example, the observation period for the May '19 contract starts on March 19, 2019 and ends on April 26, 2019.

Financial full carry is a measure of the cost, including financing costs, to hold a shipping certificate into the next delivery period. Percent financial full carry is a ratio comparing the expected revenue attainable by storing the physical grain until the next delivery period, using the nearby spread, with the cost of holding a shipping certificate into the next delivery period. High levels of percent financial full carry are caused when the nearby spread is relatively larger than the cost of carrying the delivery instrument through the next delivery period. The nearby spread should closely represent, but not exceed, the cost of physical storage or participants will enter into storage hedges and bid the price of the deferred contract down, resulting in a narrowing of the spread. This problem is exacerbated when physical storage is tight. In years of large harvests, such as 2016, demand for physical storage increases significantly, resulting in higher than average costs of grain storage and wider spreads between contracts. If the storage rates of the delivery instruments are fixed, it could become cheaper to store a delivery instrument rather than the physical commodity. Thus, market participants could take advantage of a wide spread while paying lower storage rates by holding a delivery instrument, disincentivizing them from loading out.

Garcia et al. (2014) calls the difference between the cost of physical storage and the cost of storage for a delivery instrument a "wedge," and find a strong positive correlation between the wedge and ending stocks at delivery locations, strengthening the theory that lack of available storage leads to nonconvergence. Figure 2.2 shows how a lack of available storage can create a wedge in the short run. At S_0, the storage market is in equilibrium where the cost of storing the delivery instrument is greater than or equal to the cost of storing the physical grain. If the supply of available storage decreases, from a large harvest for example, the cost of physical storage will increase; however, if the delivery instrument's storage rates are fixed, the cost of physical storage now exceeds the cost of storing the delivery instrument. Holders of delivery instruments are incentivized to store their delivery instruments rather than going through the load-out process and storing the physical commodity. Thus, a disconnect between the cash and futures market is probable. Adjemian et al. (2013) argue that the wedge forces regular facilities to set weak, or "wider," basis levels to compensate for the higher cost of storing the physical grain. Because the wedge "accumulates" over time, the regular facility will set their basis levels equal to the difference in storage rates times the expected period of time that the wedge will persist, explaining how a relatively small wedge can result in extremely wide basis.

Figure 2.2 Wedge Creation from Lack of Available Physical Storage



2.4 Nonconvergence

The HRW wheat contract and other CBOT futures contracts have seen two prolonged periods of nonconvergence in the recent past: the first from 2007 to 2011 and the second from

2016 to 2018. In the year following the first bout of nonconvergence, Irwin et al. (2008) proposed four solutions to prevent nonconvergence in CBOT futures contracts. The first was to incentivize longs to liquidate their positions before the first notice day by forcing load out or increasing the storage rate on delivery instruments. The second was to transition into a cash-settled contract. The third was to force long-only index funds to trade with speculative margins, which would only solve nonconvergence under the assumption that these traders artificially influence the futures price. That assumption was later refuted by the authors in 2011 (Irwin et al., 2011). Lastly, the authors suggested expanding the delivery capacity to increase the threat of delivery arbitrage. The CBOT utilized a combination of the first and fourth suggestions in 2011 when they introduced the VSR and expanded the number of regular facilities in the soft red winter (SRW) wheat contract. In 2011, the KCBT attempted to solve the nonconvergence issue by increasing the storage rates on warehouse receipts and adding seasonal storage rates. After the CBOT acquired the KCBT, nonconvergence began to occur in the HRW wheat contract again. In an effort to solve the nonconvergence problem, the CBOT implemented the VSR in the HRW wheat market, effective March 18, 2018. The VSR works by increasing the storage rate on shipping certificates when percent financial full carry is high.

When percent financial full carry is high, reduced levels of load-out will increase the probability of the occurrence of nonconvergence. Irwin et al. (2011) found that nonconvergence in the corn and wheat markets begins when percent financial full carry is between 75% and 80%. This can be thought of as the long's indifference point between holding the delivery instrument and holding the physical commodity. When percent financial full carry is above this point, longs will be incentivized to hold their delivery instruments instead of converting them into physical grain through the load-out process, and the cash market will suffer from lower demand. The costs associated with the load-out process and the value of the option of holding the delivery instrument to deliver against a short position in the next delivery period, explained by Aulerich, Fishe, and Harris (2010), contribute to the reason the indifference point is lower than 100% financial full carry.

For the March-May ’18 and May-July ’18 spreads, the VSR triggered an increase to $0.00265 and $0.00365 per bushel per day, respectively. The July-September ’18, September-December ’18, and December-March ’19 spreads did not trigger a change to the VSR. The first decrease to the HRW VSR occurred for the March-May ’19 spread, resulting in a VSR of $0.00265 per bushel per day.

2.5 Conclusion

Nonconvergence threatens to diminish the value of commodity futures markets by disrupting their price discovery function. The CBOT introduced the VSR to prevent nonconvergence from occurring. This study will enhance the existing literature on nonconvergence by demonstrating the relationship between high levels of percent financial full carry and nonconvergence in the HRW wheat market and illustrating the effects of nonconvergence on non-delivery locations throughout the state of Kansas.

Chapter 3 - Predicting the Probability of Nonconvergence

3.1 Introduction

The purpose of this chapter is to determine the relationship between percent financial full carry and nonconvergence in the HRW wheat market at delivery locations throughout the state of Kansas. Through the use of a multinomial logit model, the probability of nonconvergence given a level of percent financial full carry can be determined. These probabilities will allow for an analysis of the VSR's triggering mechanism.

3.2 Data

3.2.1 Daily Data

DTN's ProphetX database stores historical data for numerous statistics related to agriculture and finance including futures market prices, cash commodity prices at various locations, and interest rates. To determine nonconvergence and calculate financial full carry, daily spot closing prices, nearby and deferred contract futures closing prices, and the daily three-month London Interbank Offered Rate (LIBOR) were collected from the database. The historical cash prices start on January 1, 2004 and are updated daily, whereas the HRW wheat futures prices and three-month LIBOR rates date back to 1970 and 1986, respectively.

The daily cash spot closing prices for HRW wheat collected from DTN's ProphetX database represent the price the four grain facilities were willing to pay for a bushel of wheat at the close of the day. The four locations are the reported USDA daily truck bids in Kansas City, Cargill in Hutchinson, Cargill in Salina, and Scoular in Salina. These locations were chosen based on data availability and their proximity to delivery locations. In fact, the Hutchinson location and both Salina locations are regular facilities capable of delivering on the HRW wheat contract. The inclusion of two different regular facilities in the same switching limit will show if the model is subject to spatial sensitivity as the results from the two Salina locations should follow a similar pattern.

The closing futures price for both the nearby and deferred contract were used to calculate the "carry" or spread between the deferred and nearby contract. The carry is a measure of the expected revenue generated from storing grain into the next delivery period. Through arbitrage, the carry in the market should closely represent the cost of storing grain into the next delivery period.

The three-month LIBOR rate measures the interest rate at which banks lend money to other banks. It is used in calculating the financial full carry to account for the opportunity cost of holding grain instead of investing in an alternative.

The historical cash prices were used to calculate daily basis by subtracting the closing futures price for each day from the daily closing price in each location. Table 3.1 summarizes the daily basis, nearby futures price, spread, and three-month LIBOR.

Table 3.1 Summary of Daily Data

	# of Observations	Mean	St. Dev.	High	Low
Kansas City Basis	3407	-0.2375	0.3174	0.5175	-1.8075
Hutchinson Basis	3608	-0.2795	0.3033	0.2850	-1.2500
Salina (Cargill) Basis	3636	-0.2944	0.3167	0.2550	-1.4575
Salina (Scoular) Basis	3428	-0.3240	0.3620	0.8025	-2.5500
Nearby Futures Price	3778	5.8069	1.7862	13.3700	3.1175
3 Month LIBOR	3748	3.7004	1.7402	7.7250	2.2229
Futures Spread	3778	0.1028	0.0870	0.5425	-0.4200

It was assumed that the markets were closed if there was a day with missing futures prices. Therefore, there were numerous days without a recorded cash price in all locations and

30 days without a recorded LIBOR. The cash price does not affect the calculation of financial full carry, therefore the missing daily cash prices were ignored for the calculation of financial full carry. For the 30 missing LIBOR observations, the previous day's LIBOR was used under the assumption that day to day variations of interest rates are minuscule. Moreover, the majority of the missing LIBOR observations occurred outside of the observation period and therefore, would not affect the average financial full carry in the observation period. Daily financial full carry was calculated using the collected daily observations.

3.2.2 Financial Full Carry

Using Equation 3.1, from the CME Group's Special Executive Report 7872, the daily data was used to calculate financial full carry and ultimately the monthly data (CME Group, 2017a).

$$FC = N * [\left(\frac{i}{360}\right) * FP + P] \quad (3.1)$$

Where:

FC = Financial Full Carry

N = Number of calendar days from the first delivery day in the nearby contract to the first deliver day in the deferred contract

i = Three-month LIBOR rate + 200 basis points

FP = Settlement price for the nearby futures contract

P = Current daily storage rate for delivery instruments.

For the contracts prior to the September '11 contract, the fixed storage rate of $0.00148/bu/day was used for the current daily storage rate. The seasonal storage rates for the respective contract was used for the current daily storage rate starting with the September '11 contract and ending with the December ’17 contract. Starting with the March ’18 contract, the applicable VSR was used in the calculation of financial full carry.

Percent financial full carry is a ratio comparing the expected revenue attainable by storing the physical grain until the next delivery period, using the nearby spread, with the cost of holding a shipping certificate until the next delivery period. The formula for percent full carry is shown below (CME Group, 2017a).

$$FFC = \frac{F_0 - F_1}{FC} * 100 \quad (3.2)$$

Where:

FFC = Percent Financial Full Carry

F_0 = The price of the nearby futures contract

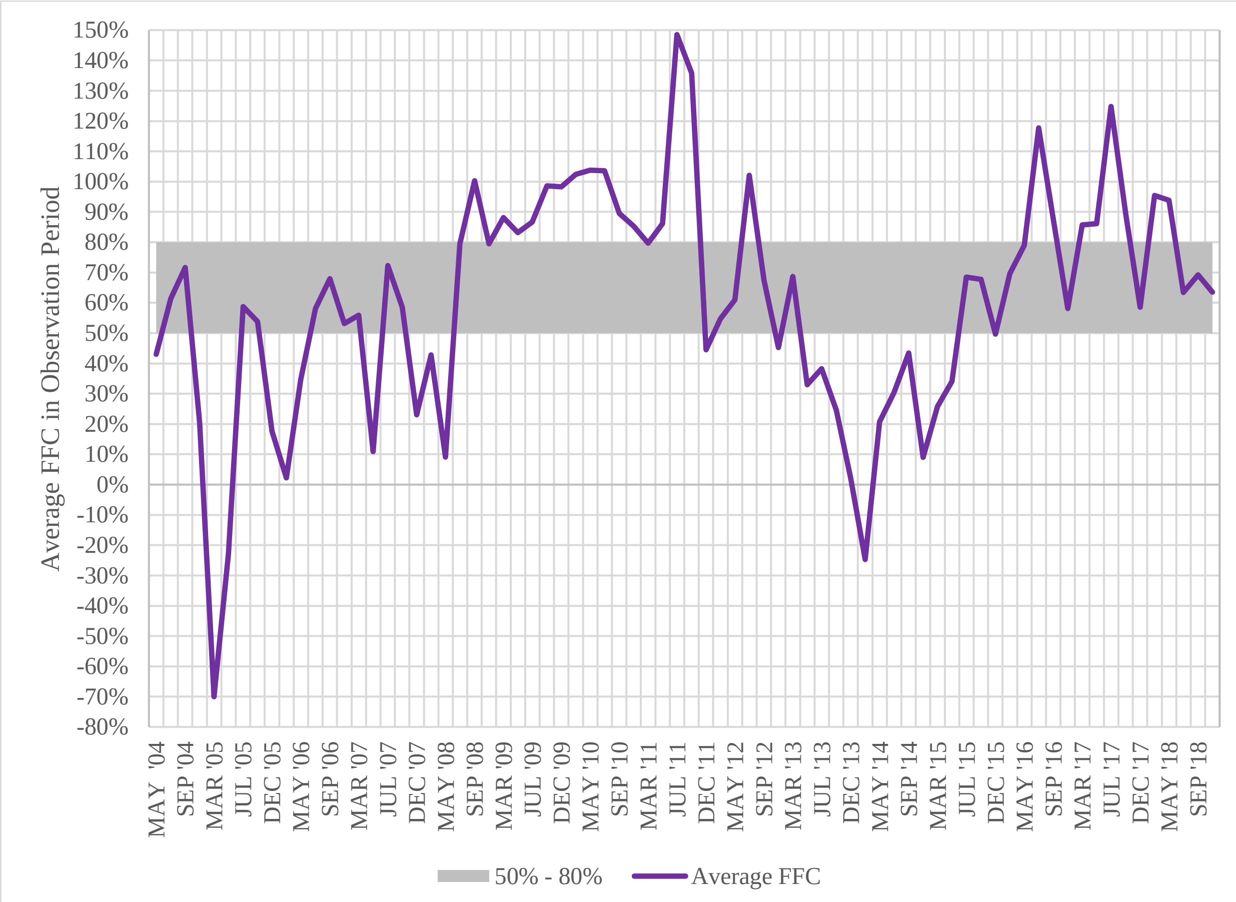
F_1 = The price of the deferred futures contract

FC = Financial Full Carry.

3.2.3 Monthly Data

The daily percent financial full carry was used to calculate the average percent financial full carry in the observation period for each contract month. The observation period for each contract begins on the 19th day of the previously expired contract month and ends on the nearby option expiration date. Since the dataset started on January 1, 2004, the first contract with a full observation period was the May ’04 contract. Therefore, the contracts studied start with the May ’04 contract and end with the December ’18 contract, resulting in 74 contracts included in the study. Figure 3.1 shows the average percent financial full carry in the observation period for each studied contract with the acceptable range of 50% to 80% highlighted in gray.

Figure 3.1 Average %FFC During the Observation Period



Average basis during the delivery period for each location was also calculated. Due to extreme variations in basis on the last day of the delivery period, basis on the last delivery day was not included in the calculation. For the March '14 and May '16 contracts, there were no reported cash prices during the delivery period from Scoular in Salina. As such, these contracts were not included in the dataset for Salina (Scoular). The full dataset is shown in Table A.1 in Appendix A. The monthly data is summarized in Table 3.2. Convergence was considered to occur when the average basis during the delivery period was within fifteen cents of the location differential specified in section 14H05 of the CBOT rulebook. Fifteen cents is roughly 2.75% of the average cash price at each location. Average basis during the delivery period is shown graphically in Figures 3.2, 3.3, 3.4, and 3.5, for Kansas City, Hutchinson, Salina (Cargill), and Salina (Scoular), respectively with the gray bands representing convergence.

Table 3.2 Summary of Monthly Data

	# of Observations	Mean	St. Dev	High	Low
FFC in Obs. Period	74	0.6053	0.3773	1.4854	-0.7001
Kansas City Basis	74	-0.1884	0.2859	0.4736	-0.8586
Hutchinson Basis	74	-0.2381	0.2773	0.1736	-0.9136
Salina (Cargill) Basis	74	-0.2520	0.2990	0.1955	-1.1536
Salina (Scoular) Basis	72	-0.2673	0.3100	0.1769	-1.0547

Figure 3.2 Average Basis During the Delivery Period in Kansas City

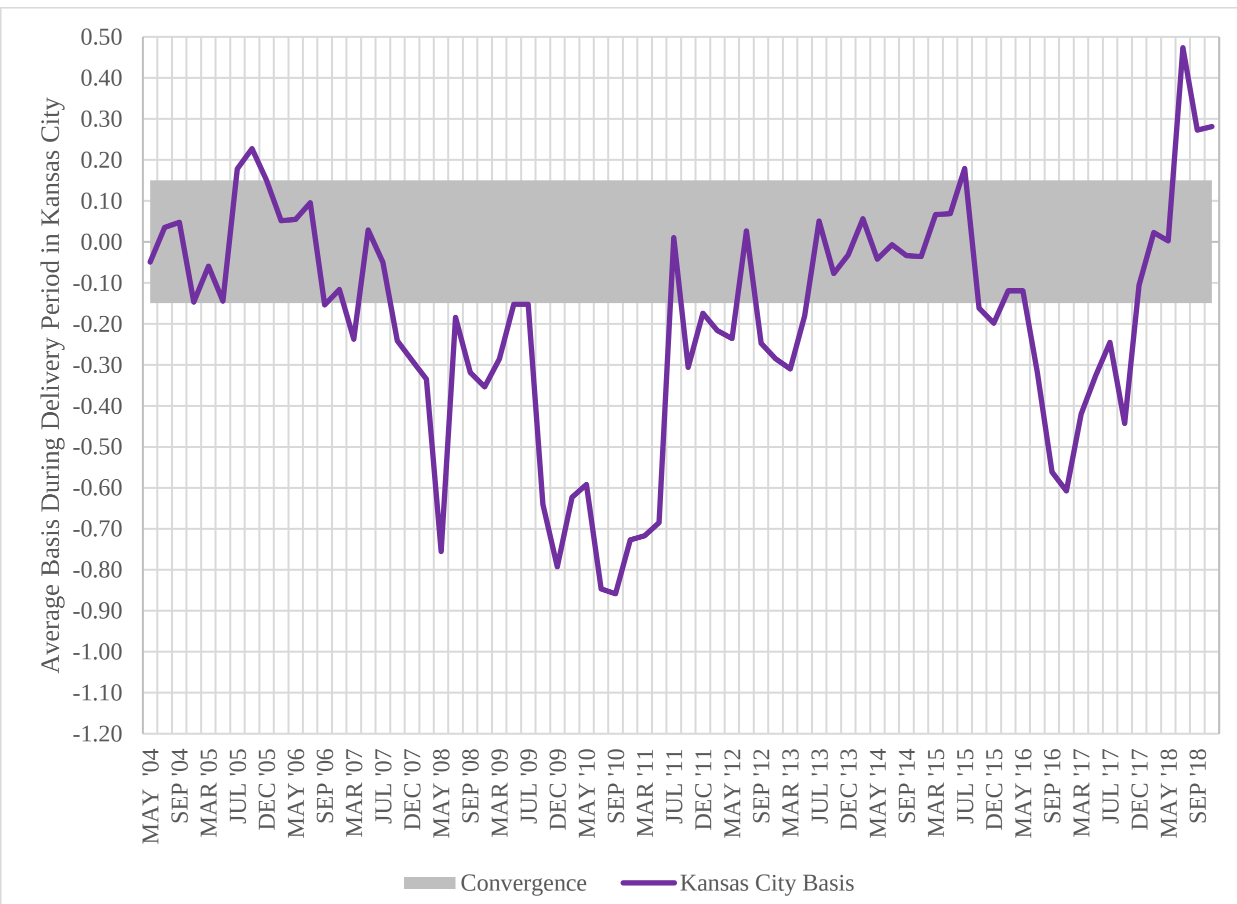


Figure 3.3 Average Basis During the Delivery Period in Hutchinson

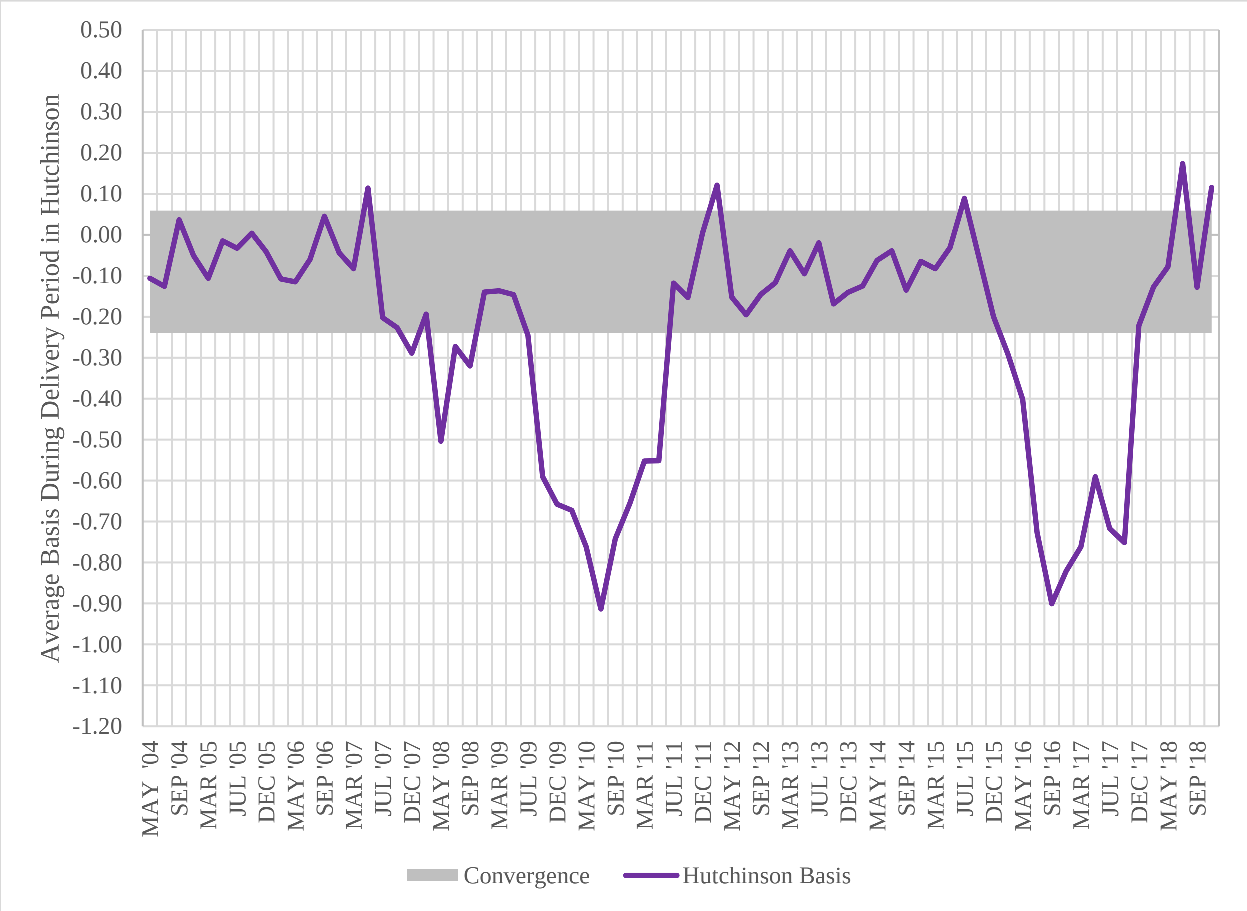


Figure 3.4 Average Basis During the Delivery Period in Salina (Cargill)

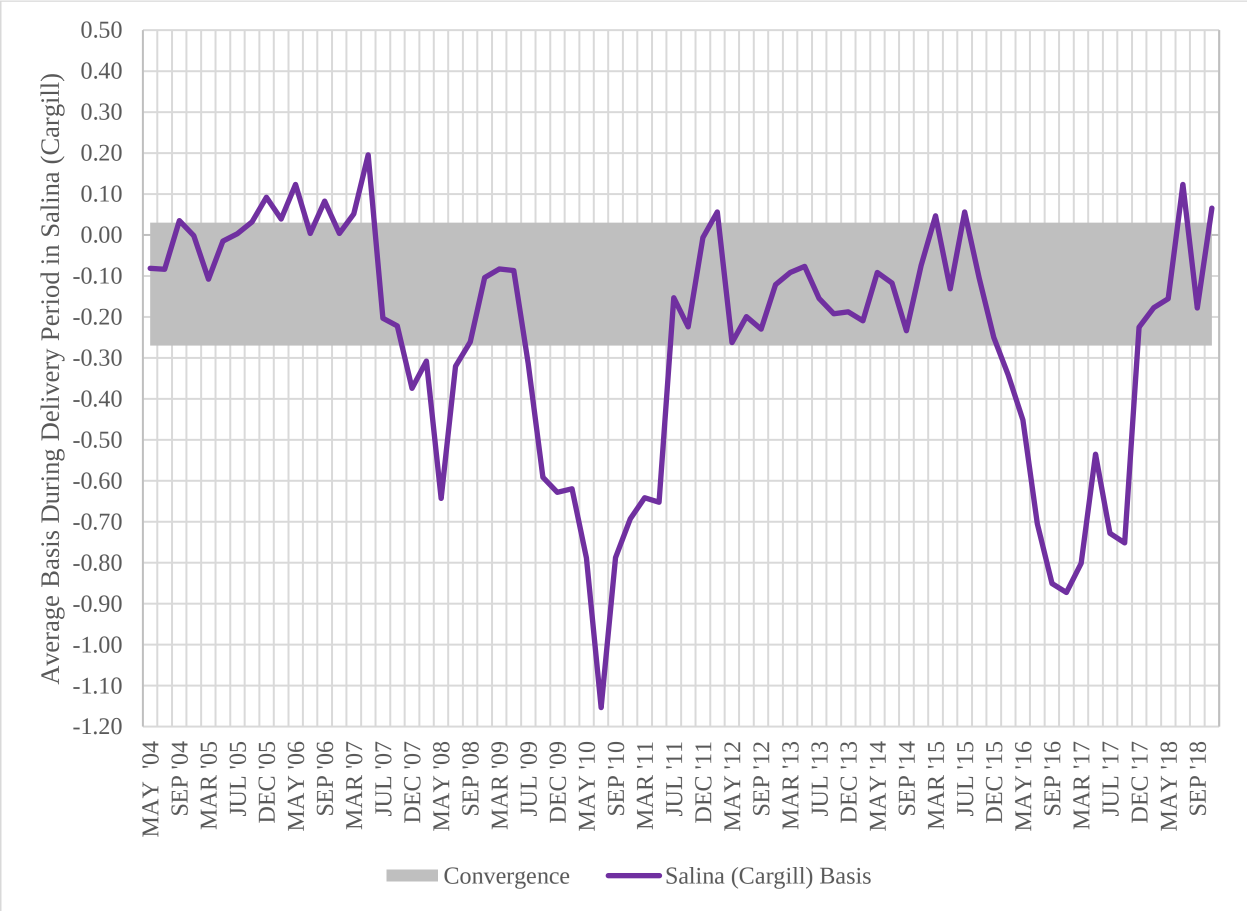
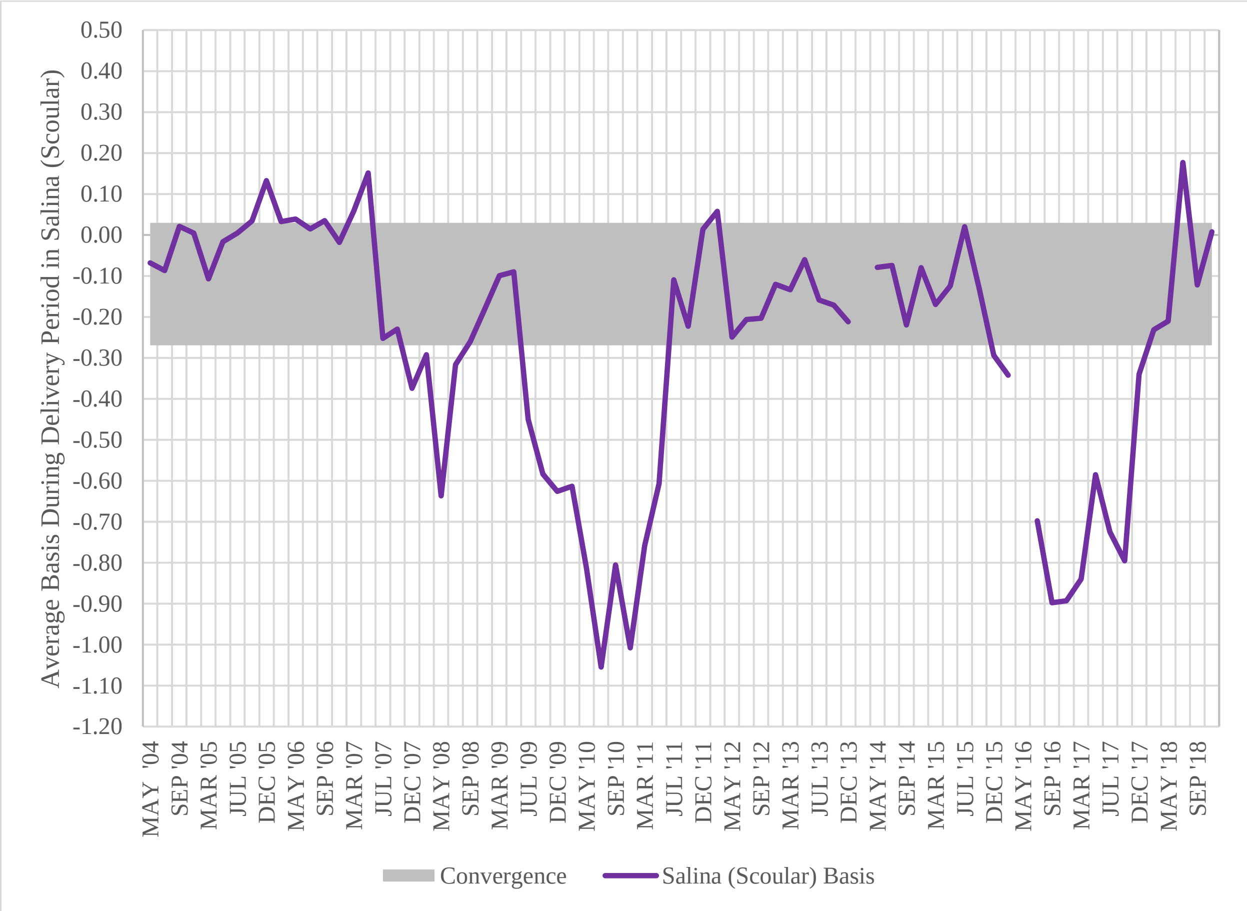


Figure 3.5 Average Basis During the Delivery Period in Salina (Scoular)



It is readily apparent from the above graphs that when percent financial full carry is high, basis in all of the studied locations tends to be weak, indicating a negative correlation between percent financial full carry and basis. Moreover, there have been two prolonged periods of exceedingly weak basis, from 2007 to 2011 and from 2016 to 2018. The first period resulted in changes to the HRW wheat contract, including the seasonal storage rates, and the second period resulted in the adoption of the VSR mechanism.

3.3 Methodology

As Cameron and Trivedi (2005) explain, multinomial models are ideal for estimating the probability of multiple discrete outcomes given a set of independent variables. The authors further examine the characteristics of numerous multinomial models including multinomial logit, conditional logit, and mixed logit models. While similar in nature to each other, multinomial logit models (MNL) have alternative-invariant regressors, or the independent variables do not vary across the choice outcomes. The basic form of the MNL, one in which the probability of the i^{th} individual chooses the j^{th} outcome given an independent regressor x, can be written as follows (Cameron and Trivedi, 2005):

$$p_{ij} = \Pr[y_i = j] = \frac{e^{x_i\beta_j}}{\sum_{l=1}^{m} e^{x_i\beta_l}} \qquad \text{for } j = 1, \ldots, m \text{ and } i = 1, \ldots, N \qquad (3.3)$$

where p_{ij} is the relative probability that i^{th} individual chooses the j^{th} outcome, x_i represents the studied attributes of the i^{th} individual's choice, and β_j is the coefficient explaining x_i's effect on p_{ij}.

As shown by Cameron and Trivedi (2005), the coefficients of MNL models are estimated using maximum likelihood estimation where the generalized log-likelihood function can be written as:

$$\mathcal{L} = lnL_N = \sum_{i=1}^{N}\sum_{j=1}^{m} y_{ij} lnp_{ij} \qquad \text{for } j = 1, \ldots, m \text{ and } i = 1, \ldots, N. \qquad (3.4)$$

When the log-likelihood function is maximized, the first order condition, shown below, must hold.

$$\frac{\partial\mathcal{L}}{\partial\beta_k} = \sum_{i=1}^{N}\sum_{j=1}^{m} \frac{y_{ij}}{p_{ij}}\frac{\partial p_{ij}}{\partial\beta_k} = 0 \qquad \text{for } j = 1, \ldots, m \text{ and } i = 1, \ldots, N \qquad (3.5)$$

To find $\frac{\partial p_{ij}}{\partial\beta_k}$, differentiate Equation 3.3 with respect to β_k, which results in:

$$\frac{\partial p_{ij}}{\partial \beta_k} = \begin{cases} \frac{e^{x_i\beta_j}}{\sum_{l=1}^{m} e^{x_i\beta_l}} x_i - \frac{e^{x_i\beta_j}}{(\sum_{l=1}^{m} e^{x_i\beta_l})^2} e^{x_i\beta_j} x_i = p_{ij}x_i - p_{ij}p_{ij}x_i \;\; if\ k = j \\ -\frac{e^{x_i\beta_j}}{(\sum_{l=1}^{m} e^{x_i\beta_l})^2} e^{x_i\beta_j} x_i = -p_{ij}p_{ik}x_i \;\; if\ k \neq j. \end{cases} \tag{3.6}$$

Equation 3.6 can be further simplified to:

$$\frac{\partial p_{ij}}{\partial \beta_k} = \delta_{ijk} p_{ij} x_i - p_{ij} p_{ik} x_i. \tag{3.7}$$

Where δ_{ijk} is a dummy variable defined as:

$$\delta_{ijk} = \begin{cases} 1\ if\ j = k \\ 0\ if\ j \neq k. \end{cases}$$

Combining equations 3.5 and 3.7 results in:

$$\frac{\partial \mathcal{L}}{\partial \beta_k} = \sum_{i=1}^{N} \sum_{j=1}^{m} \frac{y_{ij}}{p_{ij}} (\delta_{ijk} p_{ij} x_i - p_{ij} p_{ik} x_i) = \sum_{i=1}^{N} \left[\sum_{j=1}^{m} (y_{ij}\delta_{ijk} - y_{ij} p_{ik}) \right] x_i. \tag{3.8}$$

A fundamental property of MNL is that the i^{th} individual chooses one and only one of the available outcomes. This can be shown as:

$$\sum_{j=1}^{m} y_{ij} = 1. \tag{3.9}$$

Utilizing the definition of δ_{ijk} and Equation 3.8, Equation 3.9 reduces to

$$\frac{\partial \mathcal{L}}{\partial \beta_k} = \sum_{i=1}^{N} (y_{ik} - p_{ik}) x_i. \tag{3.10}$$

Therefore, when the log-likelihood equation is maximized, the first order conditions in Equation 3.5 will hold and Equation 3.10 will be equal to zero.

To prevent multicollinearity, the coefficients of the MNL model are normalized to a base outcome such that the coefficients for the base outcome are equal to zero (Cameron and Trivedi, 2005). Therefore, the coefficients measure the effect of the independent variable on the relative probability of one event occurring over the base event. However, these coefficients are measured in the units of logits and cannot be interpreted directly.

The coefficients from an MNL model are not immediately interpretable; however, the marginal effects of the regressors can be calculated by differentiating p_{ij} by the regressor. While the marginal effects at the average of the independent variables are the customary way of estimating the change in the probability of each outcome event occurring, the sole use of binary independent variables in this model makes interpreting marginal effects at the average nonsensical. Instead, it is appropriate to analyze the change in the probability of each outcome event occurring as each independent variable changes from zero to one while holding the rest of the independent variables constant. This will determine the effect of each independent variable as it "turns on," ceteris paribus.

The MNL model used to estimate the probability of a HRW wheat contract being nonconvergent given the average FFC level in the observation period can be written as:

$$p_{ij} = \Pr[c_i = j] = \frac{e^{\alpha_j + \beta_{1j} * LowFFC_i + \beta_{2j} * HighFFC_i + \beta_{3j} * Mar_i + \beta_{4j} * May_i + \beta_{5j} * Sep_i + \beta_{6j} * Dec_i}}{\sum_k^J e^{\alpha_k + \beta_{1k} * LowFFC_i + \beta_{2k} * HighFFC_i + \beta_{3k} * Mar_i + \beta_{4k} * May_i + \beta_{5k} * Sep_i + \beta_{6k} * Dec_i}} \tag{3.11}$$

for $j = Convergence, NCcashunder, NCcashover$ and $i = May'04, \ldots, Dec'18$.

Where p_{ij} is the probability that contract i exhibits convergence category j, $LowFFC_i$ is a dummy variable equal to one if the average percent financial full carry exhibited in the observation period for contract i is less than 50%, $HighFFC_i$ is a dummy variable equal to one if the average percent financial full carry exhibited in the observation period for contract i is greater than 80%, and $Mar_i, May_i, Sep_i,$ and Dec_i are binary variables equal to one for their respective contract months used to control for seasonality. This model was applied to each location separately to compare the results and determine if there is spatial heterogeneity across locations in the probability of nonconvergence given FFC levels.

The three "choice" outcomes are *Convergence*, nonconvergence with cash price under futures price (*NCcashunder*), and nonconvergence with cash price over futures price

(*NCcashover*). *Convergence* was defined to occur when the average basis during the delivery period was within 15 cents of the location differential for each location as stated in chapter 14H of the CBOT Rulebook. *NCcashunder* was defined to occur when the average basis during the delivery period was less than the location differential minus 15 cents. *NCcashover* was defined to occur when the average basis during the delivery period was more than the location differential plus 15 cents. These definitions are summarized in Table 3.3 where b_i is the average observed basis during the delivery period for the respective location.

Table 3.3 Defined Convergence Outcomes

Location	***NCcashunder***	***Convergence***	***NCcashover***
Kansas City	$b_i < -0.15$	$-0.15 < b_i < 0.15$	$b_i > 0.15$
Hutchinson	$b_i < -0.24$	$-0.24 < b_i < 0.06$	$b_i > 0.06$
Salina (Cargill)	$b_i < -0.27$	$-0.27 < b_i < 0.03$	$b_i > 0.03$
Salina (Scoular)	$b_i < -0.27$	$-0.27 < b_i < 0.03$	$b_i > 0.03$

The 30-cent window is admittedly arbitrary; however, in order to divide the outcomes into discrete groups, a strict definition of nonconvergence was required. A summary of the number of contracts that displayed each outcome category is displayed in Table 3.4.

Table 3.4 Summary of Contracts that Exhibited Convergence Outcomes

Location	**# of *Convergence***	**# of *NCcashunder***	**# of *NCcashover***	**Total Contracts**
Kansas City	29	38	7	74
Hutchinson	46	23	5	74
Salina (Cargill)	38	23	13	74
Salina (Scoular)	39	24	9	72

The base category for the MNL model was set to the convergence outcome as convergence is expected to naturally occur when the futures market is working efficiently.

3.4 Results

The MNL model in Equation 3.11 was applied to each location's dataset separately. The results are shown in Table 3.5. While the coefficients are not interpretable, their significance should be noted. At all locations, the effects of a percent financial full carry over 80% significantly impacts the likelihood of cash under futures nonconvergence at the 99% confidence level. The results do not show a strong presence of seasonality, therefore, the probability of nonconvergence, relative to the July contract month, does not vary throughout the marketing year after controlling for the average percent financial full carry in the observation period.

For the cash over futures outcome, no coefficients at any of the locations are statistically significant. This is likely due to the relatively low number of studied contracts that exhibited this outcome in any of the locations.

The pseudo R^2 number is McFadden's R^2 and is a measure of the goodness of fit for a logistic regression (Hausman and McFadden, 1984). While the McFadden R^2 cannot be interpreted the same as the R^2 from an ordinary-least squares regression, it provides a statistic for how well the model fits the data.

Table 3.5 MNL Model Results

		Location							
		Kansas City		Hutchinson		Salina (Cargill)		Salina (Scoular)	
Outcome: NCcashunder	*LowFFC*	-1.5422	**	-1.4801		-1.0344		-0.5493	
		(0.7258)		(0.9521)		(0.8630)		(0.8252)	
	HighFFC	1.5336	*	2.1058	***	1.6626	**	2.0436	***
		(0.8054)		(0.7118)		(0.7221)		(0.7523)	
	Mar	1.5332		0.1912		0.9123		0.9290	
		(0.9688)		(1.0040)		(0.9830)		(0.9859)	
	May	1.2122		0.6074		0.4904		0.0464	
		(0.9797)		(1.0387)		(0.9621)		(0.9908)	
	Sep	2.0114	**	-0.1452		-0.3468		-0.3667	
		(1.0207)		(0.9245)		(0.9226)		(0.9279)	
	Dec	2.3141	**	0.8553		0.6060		1.2959	
		(1.0398)		(1.0340)		(0.9707)		(0.9480)	
	Constant	-1.0147		-1.4575	*	-1.2291		-1.5525	**
		(0.8227)		(0.8063)		(0.7682)		(0.7826)	
Outcome: NCcashover	*LowFFC*	-2.2992	*	-1.9949		-0.7443		-0.4363	
		(1.3114)		(1.2936)		(0.7715)		(0.9152)	
	HighFFC	-16.6366		-17.1018		-17.3244		-15.6054	
		(2424.7890)		(3738.5110)		(2562.0980)		(1420.0080)	
	Mar	-16.6009		-0.5656		1.2331		1.6718	
		(2790.7480)		(1.3786)		(1.0973)		(1.3198)	
	May	-16.3297		0.1101		0.2825		1.0769	
		(2937.4250)		(1.5080)		(1.2283)		(1.4773)	
	Sep	0.3548		-17.3239		0.5040		0.7776	
		(1.2273)		(3470.1210)		(1.0873)		(1.3378)	
	Dec	0.5818		-0.5183		-0.1118		0.0417	
		(1.2785)		(1.3953)		(1.1709)		(1.5487)	
	Constant	-0.0716		-0.7861		-0.8823		-1.8159	*
		(0.7763)		(0.8392)		(0.8319)		(1.0821)	
	Pseudo R2	0.2714		0.2634		0.1909		0.1890	

Note: Standard errors in parenthesis

Significance levels: *** = significant at 99% CI, ** = significant at 95% CI, * = significant at 90% CI

Due to the exclusive use of binary independent variables, the change in the probability of each convergence outcome due to a change in an independent variable was calculated instead of marginal effects. In order to maintain consistency between the locations, the base value for each independent variable was set to zero, thus, at the base outcome, average percent financial full carry is assumed to be between 50% and 80%, the band where convergence is expected to occur, and the contract month is assumed to be a July contract. Tables 3.6, 3.7, 3.8, and 3.9 show the base values of the independent variables and their standard deviations, the probability of each convergence outcome at the base values of independent variables, and the change in probability of each convergence outcome when each independent variable changes from zero to one for Kansas City, Hutchinson, Salina (Cargill), and Salina (Scoular), respectively. At the base levels of the independent variables, convergence is the most likely outcome for each location as expected. For all locations, the probability of cash under futures nonconvergence increases more than 40% when the average percent financial full carry during the observation period is greater than 80%, validating the findings of Irwin et al. (2011) that nonconvergence begins when percent financial full carry is between 75% and 80%.

Tables 3.6, 3.7, 3.8, and 3.9 can be used to calculate the probability of a convergence outcome for the July contract given a level of percent financial full carry by adding the change in probability to the probability of the outcome at the base values of the independent variables. For example, the probability of cash under futures nonconvergence in Kansas City given an average percent financial full carry greater than 80% in the observation period is equal to 62.7%, which is the base value of 15.8% plus the change of 46.9%. The probability of each convergence outcome given a percent financial full carry level is shown in Table 3.10.

Table 3.6 Change in Probability of Convergence Outcomes in Kansas City

a	*LowFFC*	*HighFFC*	*Mar*	*May*	*Sep*	*Dec*
X =	0	0	0	0	0	0
StDev(X) =	0.4762	0.4660	0.3943	0.4048	0.4048	0.4048

b			*NCcashunder*	*NCcashover*	*Convergence*
Pr(y|x)			15.81%	40.59%	43.60%

c		Average Change	*NCcashunder*	*NCcashover*	*Convergence*
LowFFC	0 →1	27.87%	-9.18%	-32.61%	41.80%
HighFFC	0 →1	31.25%	46.88%	-40.59%	-6.29%
Mar	0 →1	31.25%	46.87%	-40.59%	-6.28%
May	0 →1	27.06%	39.11%	-40.59%	1.48%
Sep	0 →1	25.32%	37.98%	-14.24%	-23.75%
Dec	0 →1	28.07%	42.10%	-14.29%	-27.81%

Note: [a] Base values for the independent variables.

[b] Probability of each convergence outcome given the base values of the independent variables.

[c] Change in probability of each convergence outcome given a change in one independent variable, ceteris paribus.

Table 3.7 Change in Probability of Convergence Outcomes in Hutchinson

a	*LowFFC*	*HighFFC*	*Mar*	*May*	*Sep*	*Dec*
X =	0	0	0	0	0	0
StDev(X) =	0.4762	0.4660	0.3943	0.4048	0.4048	0.4048

b			NCcashunder	NCcashover	Convergence
Pr(y|x)			13.79%	26.98%	59.23%

c		Average Change	NCcashunder	NCcashover	Convergence
LowFFC	0 →1	20.31%	-9.04%	-21.43%	30.46%
HighFFC	0 →1	34.58%	51.87%	-26.98%	-24.89%
Mar	0 →1	6.79%	4.51%	-10.19%	5.68%
May	0 →1	5.52%	8.28%	-0.71%	-7.57%
Sep	0 →1	17.99%	2.97%	-26.98%	24.01%
Dec	0 →1	10.88%	16.32%	-12.07%	-4.25%

Note: [a] Base values for the independent variables.

[b] Probability of each convergence outcome given the base values of the independent variables.

[c] Change in probability of each convergence outcome given a change in one independent variable, ceteris paribus.

Table 3.8 Change in Probability of Convergence Outcomes in Salina (Cargill)

a	*LowFFC*	*HighFFC*	*Mar*	*May*	*Sep*	*Dec*
X =	0	0	0	0	0	0
StDev(X) =	0.4762	0.4660	0.3943	0.4048	0.4048	0.4048

b	*NCcashunder*	*NCcashover*	*Convergence*
Pr(y|x)	17.14%	24.25%	58.60%

c		Average Change	*NCcashunder*	*NCcashover*	*Convergence*
LowFFC	0 →1	12.19%	-9.15%	-9.14%	18.28%
HighFFC	0 →1	29.02%	43.53%	-24.25%	-19.27%
Mar	0 →1	17.90%	5.99%	20.85%	-26.84%
May	0 →1	6.17%	6.43%	2.83%	-9.26%
Sep	0 →1	7.97%	-6.21%	11.96%	-5.75%
Dec	0 →1	7.32%	10.99%	-4.84%	-6.15%

Note: [a] Base values for the independent variables.

[b] Probability of each convergence outcome given the base values of the independent variables.

[c] Change in probability of each convergence outcome given a change in one independent variable, ceteris paribus.

Table 3.9 Change in Probability of Convergence Outcomes in Salina (Scoular)

a	*LowFFC*	*HighFFC*	*Mar*	*May*	*Sep*	*Dec*
X =	0	0	0	0	0	0
StDev(X) =	0.4747	0.4695	0.3873	0.3986	0.4090	0.4090

b	*NCcashunder*	*NCcashover*	*Convergence*
Pr(y|x)	15.40%	11.84%	72.76%

c		Average Change	*NCcashunder*	*NCcashover*	*Convergence*
LowFFC	0 →1	5.81%	-5.45%	-3.27%	8.71%
HighFFC	0 →1	31.09%	46.63%	-11.84%	-34.80%
Mar	0 →1	20.75%	6.92%	24.21%	-31.12%
May	0 →1	10.84%	-2.35%	16.27%	-13.91%
Sep	0 →1	7.84%	-5.63%	11.76%	-6.13%
Dec	0 →1	16.27%	24.41%	-3.11%	-21.30%

Note: [a] Base values for the independent variables.

[b] Probability of each convergence outcome given the base values of the independent variables.

[c] Change in probability of each convergence outcome given a change in one independent variable, ceteris paribus.

Table 3.10 Probability of Convergence Outcomes Given FFC Levels

	FFC Level[a]	*Convergence*	*NCcashunder*	*NCcashover*
Kansas City	(0,0)	43.60%	15.81%	40.59%
	(1,0)	85.40%	6.62%	7.98%
	(0,1)	37.31%	62.69%	0.00%
Hutchinson	(0,0)	59.23%	13.79%	26.98%
	(1,0)	89.69%	4.75%	5.56%
	(0,1)	34.34%	65.66%	0.00%
Salina (Cargill)	(0,0)	58.60%	17.14%	24.25%
	(1,0)	76.89%	8.00%	15.12%
	(0,1)	39.33%	60.67%	0.00%
Salina (Scoular)	(0,0)	72.76%	15.40%	11.84%
	(1,0)	81.47%	9.96%	8.57%
	(0,1)	37.96%	62.04%	0.00%

Note: [a] (*LowFFC*, *HighFFC*) values. *LowFFC*=1 if the average percent financial full carry in the observation period is less than 50%. *HighFFC*=1 if the average percent financial full carry in the observation period is greater than 80%.

Unsurprisingly, convergence is the most likely outcome when the average percent financial full carry is between 50% and 80% for all locations. While the margin is larger in the other locations, convergence is only 3% more likely to occur than cash over futures nonconvergence in Kansas City.

When high levels of average percent financial full carry are observed, the probability of cash over futures nonconvergence is equal to zero and cash under futures nonconvergence becomes the most likely outcome for all locations, further strengthening the link between high levels of percent financial full carry and weak basis. This is likely due to holders of shipping certificates carrying them into the next delivery period rather than going through the load out process, thus depressing the demand in the cash market. Moreover, when the VSR triggers an increase in storage rates on shipping certificates, the percent financial full carry will decrease, assuming the spread remains constant. Therefore, the VSR will lower the probability of sustained periods of nonconvergence.

Interestingly, cash over futures nonconvergence is most likely to occur in all locations when the average percent financial full carry is between 50% and 80%. This is likely due to the relatively low number of contracts that experienced cash over futures nonconvergence. Convergence is most likely to occur at all locations when the average percent financial full carry in the observation period is less than 50%, indicating that the lower limit of the VSR may not be intended to reduce the chance of cash over futures nonconvergence, but rather to maintain the lowest VSR that prevents severe cash under futures nonconvergence. Moreover, backwardation, or when the deferred contract's price is lower than the nearby contract's price, causes negative percent financial full carry values while typically exhibiting convergence, thus increasing the probability of convergence in contract months with low percent financial full carry.

3.5 Conclusions

The high probability of nonconvergence occurring when percent financial full carry levels are above 80% validates the theory behind the VSR. The VSR will incrementally lower percent financial full carry levels by increasing the cost of holding a shipping certificate. The incremental adjustment could be slow to correct large shocks in the market, but sustained periods of nonconvergence should not occur with the VSR.

Chapter 4 - Basis Expectations During Nonconvergence

4.1 Introduction

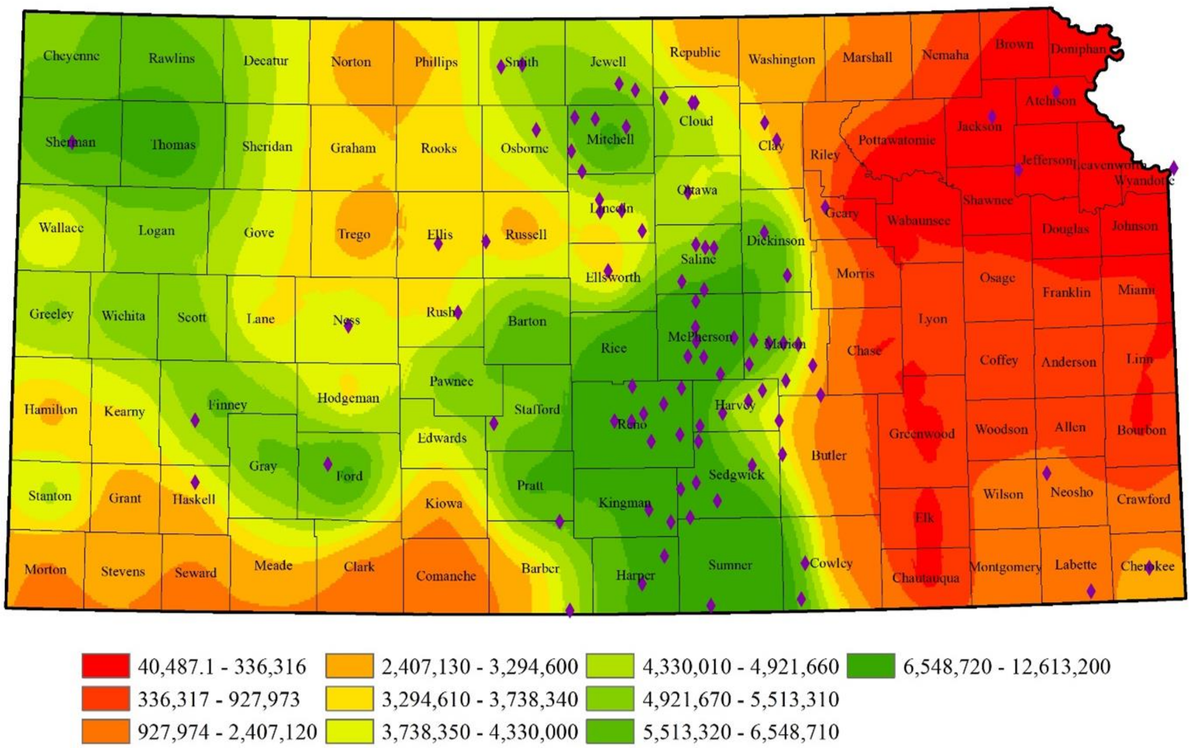
The purpose of this chapter is to determine the spatial effects of nonconvergence on basis at outlying grain handling facilities throughout the state of Kansas. By understanding the effects of nonconvergence on basis, producers and consumers of HRW wheat can better predict basis movements and improve their marketing strategies.

The spatial effects of nonconvergence on basis is a relatively new topic. Karali, McNew, and Thurman (2018) analyzed the effects of nonconvergence in the SRW wheat market on basis at 106 grain handling facilities within 100 miles of Toledo, Ohio from 2005 to 2013 by estimating basis in outlying locations using a location specific basis comovement variable. In the years of their study, the SRW wheat market exhibited one significant period of nonconvergence before the VSR adjusted the market into convergence. The comovement variable's coefficient was allowed to vary between the three periods: before nonconvergence, during nonconvergence, and after nonconvergence. They found that during nonconvergence, basis comovement was statistically stronger for a portion of the non-delivery locations, and basis comovement returned to their pre-nonconvergence levels after the period of nonconvergence. They interpreted their results in two ways; (1) weak basis in a delivery location results in weak basis in outlying locations, and (2) nonconvergence is caused by an incorrect specification of the futures contract rather than the supply and demand fundamentals in the cash market (Karali et al., 2018). The authors are referring to the "wedge" propagated by Garcia et al. (2014) and Adjemian et al. (2013) and discussed in chapter two.

4.2 Data

Daily closing spot prices from 90 locations throughout the state were collected from DTN's ProphetX database from January 2, 2004 to March 1, 2019. Spot prices represent the amount the elevator is willing to pay per bushel of #1 HRW wheat without accounting for any premiums or dockages due to quality aspects, such as moisture content and protein levels. These locations represent five regular facilities in the switching limits of Salina, Abilene, and Hutchinson, two non-regular facilities in the delivery locations of Wichita and Hutchinson, 79 non-regular facilities in non-delivery locations, and four USDA daily grain bid estimates for Dodge City, Garden City, Goodland, and Kansas City, MO. These locations were chosen based on the completeness of their data in the ProphetX database. The studied locations are more heavily clustered in the South-central area of the state where HRW wheat production is highest. Figure 4.1 shows the studied locations, shown by the purple diamonds, superimposed on a map displaying the average HRW wheat production from 2009-2018, created from county-level USDA NASS data (USDA-NASS, 2019).

Figure 4.1 Average HRW Wheat Production by County (bu), 2009-2018

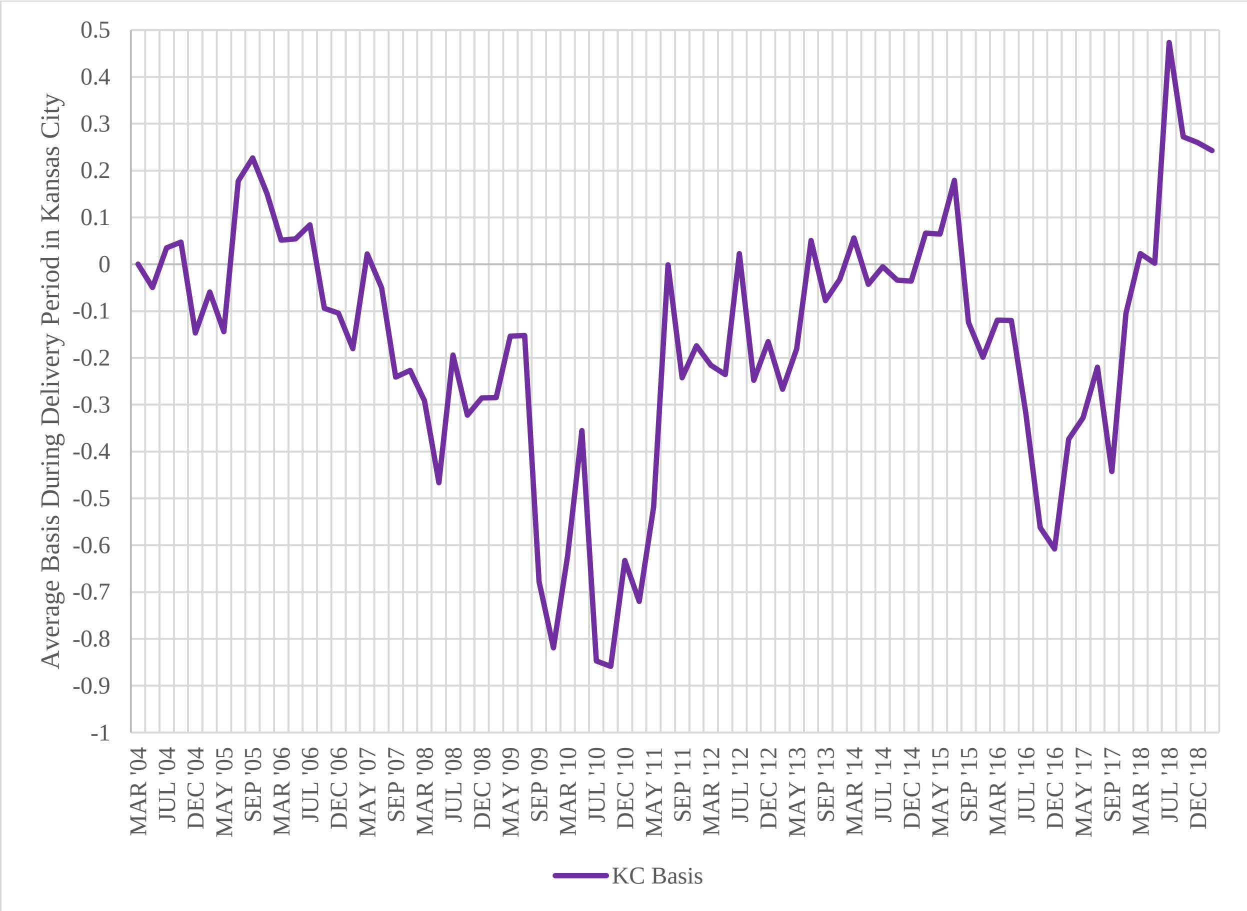


Source: USDA-NASS (2019).

Futures prices for the nearby contract were also collected from the ProphetX database. There are five contract months per year in the HRW wheat market: March, May, July, September, and December. A contract is the nearby contract when it has the fewest days to expiration of the available contracts. Each contract expires on the 15th day, or the last business day prior to the 15th, of the respective month. For example, the May '19 contract will expire on May 15, 2019. The July contract is the harvest contract as it is the nearby contract when the majority of the HRW wheat is harvested. Moreover, the July contract is the first contract that incorporates the supply and demand shifters from the new crop each year. Days without a reported futures price were assumed to be a weekend or holiday and were removed from the dataset.

Basis for each location was calculated by subtracting the nearby futures price from the respective spot closing price for each day and is measured in dollars per bushel. Basis accounts for local supply and demand shifters and, through the threat of arbitrage, transportation costs to a location with higher prices. Kansas City was chosen as the base for comparisons over the other delivery locations due to its barge loading facilities on the Missouri River and the ease of transport to the Gulf of Mexico for export. Deliveries at Kansas City occur at the par value of the contract, as shown in rule 14H05 in the KC HRW Wheat Chapter of the CBOT Rulebook (CME Group, 2019b). Following Irwin et al. (2008), cash prices and futures prices are expected to converge at time of the contract's expiration in delivery locations, therefore during the delivery period, basis in Kansas City is expected to be equal to zero. To determine the periods of nonconvergence, the average basis at Kansas City during the delivery period of each contract was calculated. Regarding the load-out costs, estimated at $0.08 by Irwin et al. (2011), any contract with an average delivery period basis at Kansas City less than eight cents under par value is considered nonconvergent. Only cash-under-futures nonconvergence is considered because of its pervasive nature in the analyzed time period. Figure 4.2 shows the average basis in Kansas City during the delivery period. It is evident that there were two prolonged periods of nonconvergence. The first occurred from 2009 to 2011, and the second from 2016 to 2018. Of the 76 studied contracts, 44 contracts were defined as nonconvergent at the eight cent under level.

Figure 4.2 Average Basis During the Delivery Period in Kansas City



Daily basis in Kansas City was lagged by one day, excluding weekends and holidays. The lagged value will be used as a comovement variable to estimate basis in outlying locations. The lag was used under the assumption that basis is adjusted at the same time in all locations and outlying locations adjust their basis after seeing the change in basis in Kansas City. Observations missing the lagged Kansas City basis and basis in an outlying location were removed from the dataset, resulting in an unbalanced panel dataset with 287,297 observations over 3,383 days. The are 3,192 observations per location, on average. A condensed summary of the daily basis, lagged Kansas City basis, and futures prices is shown in Table 4.1. A full summary of the observations by location is shown in Table B.1 in Appendix B.

Table 4.1 Summary of Daily Observations

	# of Obs	Mean	St. Dev	High	Low
Basis	287,297	-0.4895	0.3408	1.1150	-2.5500
Lagged KC Basis	3,383	-0.2174	0.3183	0.5175	-1.8075
Futures	3,383	5.6428	1.7016	13.3700	3.1175

A dummy variable was created for each of the five contract months per year to control for the seasonality of basis. There were 76 separate contracts covering the 3,584 days studied. Table 4.2 shows a summary of the contracts included in the study.

Table 4.2 Summary of Contracts Studied

Month	March	May	July	September	December	Total
# of Obs	820	580	571	562	850	3383
# of Contracts	16	15	15	15	15	76

4.3 Methodology

While the causes of nonconvergence at delivery locations are well documented, the effects of nonconvergence on cash prices at non-delivery locations are under-researched, especially for the HRW wheat contract. Karali et al. (2018) modeled basis at non-delivery locations around Toledo, Ohio as a percentage of basis at the delivery location for SRW wheat plus a location-based fixed effect to account for transportation costs and local supply and demand factors from the March ’05 contract through the May ’13 contract. This allowed them to determine the rate of basis movement at non-delivery locations relative to the delivery point. For the contract months analyzed by Karali et al. (2018), there was only one period of nonconvergence; from the May ’08 to the Dec ’09 contracts. The CBOT introduced the VSR mechanism in the SRW wheat contract in 2010; after which, nonconvergence was not present. As a result, Karali et al. (2018) analyzed three time periods: pre-nonconvergence, nonconvergence, and post-nonconvergence. They found that during periods of nonconvergence, on average, basis at non-delivery locations follows changes in basis at the delivery location more closely than the previous period of convergence, signaling a disconnect of futures and cash prices throughout the studied area. Moreover, in the post-nonconvergence period, basis comovement decreased to levels similar to the pre-nonconvergence period.

A model was developed to calculate expected basis at each location given basis in Kansas City the previous day. Hauser, Garcia, and Tumblin (1990) and Taylor, Dhuyvetter, and Kastens (2006) determined that expected basis can be adequately modeled using naïve pricing, further supporting its use in this study. The model used to find expected basis is given by:

$$b_{ikt} = FE_i + CM_j + \delta_i b_{kt-1}^{KC} + \gamma_i D_k^{nonconvergence} \tag{4.1}$$

where:

$i = 1, \ldots, 90$ (grain handling locations)

$j = 1, \ldots, 5$ (nearby contract month, i.e. March, May, July, September, December)

$k = 1, \ldots, 76$ (all contracts from March 2004-March 2019)

$t = 1, \ldots, 3383$ (date).

The dependent variable, represented by b_{ikt}, is equal to the basis ($/bu) at location i for contract k on day t. FE_i represents the fixed effects for location i. CM_j is a dummy variable for the contract month j to control for seasonality differences in basis. b_{kt-1}^{KC} is the basis ($/bu) at Kansas City for contract k on day $t-1$. Basis at Kansas City is lagged to allow the various locations to react to a change in basis at the delivery location using the assumption that elevator managers look at basis in Kansas City at the end of the day and adjust basis at their location accordingly. D_k^{noncon} is a dummy variable denoting the presence of nonconvergence in contract k. The coefficient δ_i measures the basis at location i as a percentage of basis at Kansas City. The coefficient γ_i measures the change in basis at location i when nonconvergence is present.

Location-based fixed effects were included in the model to account for transportation cost differentials and local supply and demand factors. The location-based fixed effect allows for a fair comparison of the basis comovement values between locations. Kansas City is the base value with which the rest of the locations are compared. Therefore, the fixed effects coefficients can be thought of as the expected basis at location i given basis at Kansas City is equal to zero during any given July contract.

The contract month dummy variable controls for seasonal patterns in basis and prevents biasing the effects of nonconvergence. The July contract is omitted to be used as the base due to its temporal alignment with the majority of HRW wheat harvest throughout the state. The cyclical nature of grain production, in conjunction with supply and demand, theoretically dictates that local basis will be weakest during or immediately after harvest. The increased supply of grain following harvest will depress local prices, thus weakening basis. As grain is moved from the location, supply will dwindle, and local basis should strengthen until the next harvest.

The basis comovement coefficient measures the magnitude of a change in basis at location i as a percentage of a change in basis at Kansas City the previous day. In a period of convergence, the rate of change in basis at location i given a change in basis in Kansas City is equal to δ_i. Therefore, the expected basis during a period of convergence at location i given a change in basis in Kansas City the previous day can be determined using the formula:

$$Eb_{ikt} = b_{ikt-1} + \delta_i * \Delta b_{kt-1}^{KC}. \qquad (4.2)$$

The most interesting coefficient is the change in basis due to nonconvergence. This coefficient will explain how basis at non-delivery locations is affected by nonconvergence. It measures the change in basis due to nonconvergence. By allowing it to vary by location, the spatial effects of nonconvergence on basis can be interpreted. In a period of nonconvergence, the expected change in basis at location i given a change in basis at Kansas City can be calculated using the formula:

$$\Delta b_{ikt} = \delta_i * \Delta b_{kt-1}^{KC} + \gamma_i. \tag{4.3}$$

Lastly, the expected basis during a period of nonconvergence at location i given a change in basis in Kansas City the previous day is calculated using the formula:

$$Eb_{ikt} = b_{ikt-1} + \delta_i * \Delta b_{kt-1}^{KC} + \gamma_i. \tag{4.4}$$

4.4 Results

4.4.1 Eight Cent Under Model

The model shown in Equation 4.1 is estimated using OLS regression with White-Huber standard errors to account for heteroskedasticity present in the dataset. A summary of the regression results is shown in Table 4.3. The full regression results are displayed in Table B.2 in Appendix B.

Table 4.3 Summary of Regression Results (8 cent under NC)

	Coefficients			
	Fixed Effects (FE_i)	**Contract Month (CM_j)**	**Comovement (δ_i)**	**Nonconvergence (γ_i)**
n	89	4	90	90
Mean	-0.3155	0.0336	79.82%	-0.0345
Min	-0.4402	0.0023	69.49%	-0.1123
Max	0.0248	0.0496	90.52%	0.0152
10th Percentile	-0.3801	0.0115	76.38%	-0.0790
90th Percentile	-0.2711	0.0495	84.21%	-0.0125
Counts:				
Significantly[1] >0	1	3	90	0
Significantly[1] <0	88	0	0	49
Number >0	1	4	90	3
Number <0	88	0	0	87
Prob > F = 0				
R-squared = 0.8967				

Note: [1]Significant at the 95% confidence interval.

The average location specific fixed effect, FE_i, was \$0.32 under the Kansas City basis. Moreover, all locations, except Salina – ADM, were significantly less than zero, meaning that in most areas in the state, basis will be weaker than at Kansas City. The difference between a regular facility and non-regular facility in Hutchinson, the only such pairing present in the dataset, is \$0.17 per bushel, indicating that regular facilities may offer a higher cash price than their non-regular counterparts. This could be due to the regular facility having a higher demand for grain to cover outstanding warehouse receipts.

The average comovement coefficient, δ_i, is 79.82%, which can be interpreted as a 10 cent increase in basis in Kansas City would result in an expected eight cent increase in basis at an average outlying location. Comovement was statistically greater than zero at all locations, indicating that the rate of basis change in outlying locations occurs in the same direction, albeit with a lower magnitude, as the rate of basis change in a delivery location, reaffirming the theory that basis is linked by the threat of arbitrage.

The average effect of nonconvergence on basis, γ_i, was a decrease of $0.03. This weakening in basis can be interpreted as weak basis in a delivery location results in weaker than expected basis in outlying locations, ceteris paribus. This effect was statistically significant in 49 locations.

As expected, the basis seasonality variable, CM_j, shows that basis is expected to be weakest during the July contract months reinforcing the theory that basis is weakest during and immediately following harvest. On average, basis is expected to be $0.0336 per bushel higher for a contract other than the July contract. The full regression results for basis seasonality is shown in Table 4.4. As expected, the March and May contracts are the largest, and exhibit stronger basis levels relative to the July contract.

Table 4.4 Seasonality of Basis (8 cent under NC)

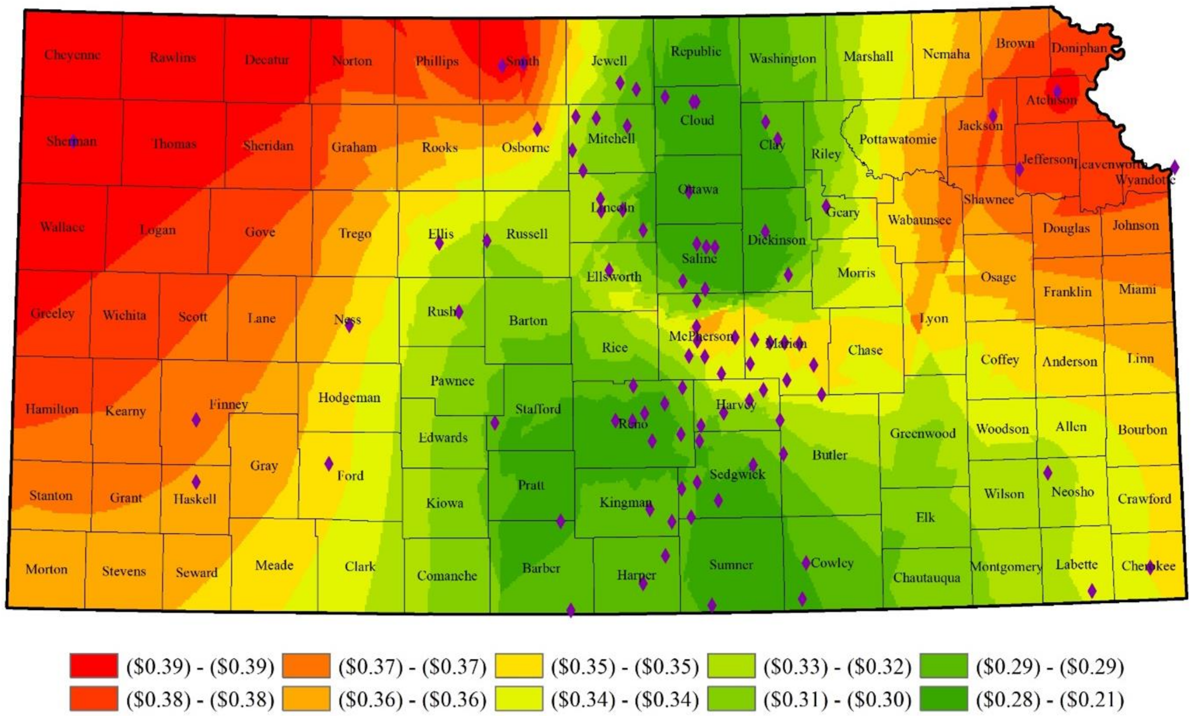
Delivery Month	$\boldsymbol{CM_j}$	
March	0.0493 (0.0011)	***
May	0.0496 (0.0012)	***
September	0.0023 (0.0012)	*
December	0.0330 (0.0011)	***

Note: Standard errors in parenthesis
Significance levels: *** = significant at 99% CI, ** = significant at 95% CI, * = significant at 90% CI

The coefficients were then matched to their respective locations to analyze their spatial properties. These values are then interpolated across space using a spherical kriging method, categorized into quantiles, and plotted on a map of the state. Kriging interpolates data over space to predict a value in areas without data by fitting a function to nearby points with data. Kriging considers the variation of the known data and minimizes predicted errors in the estimation (Oliver and Webster 1990).

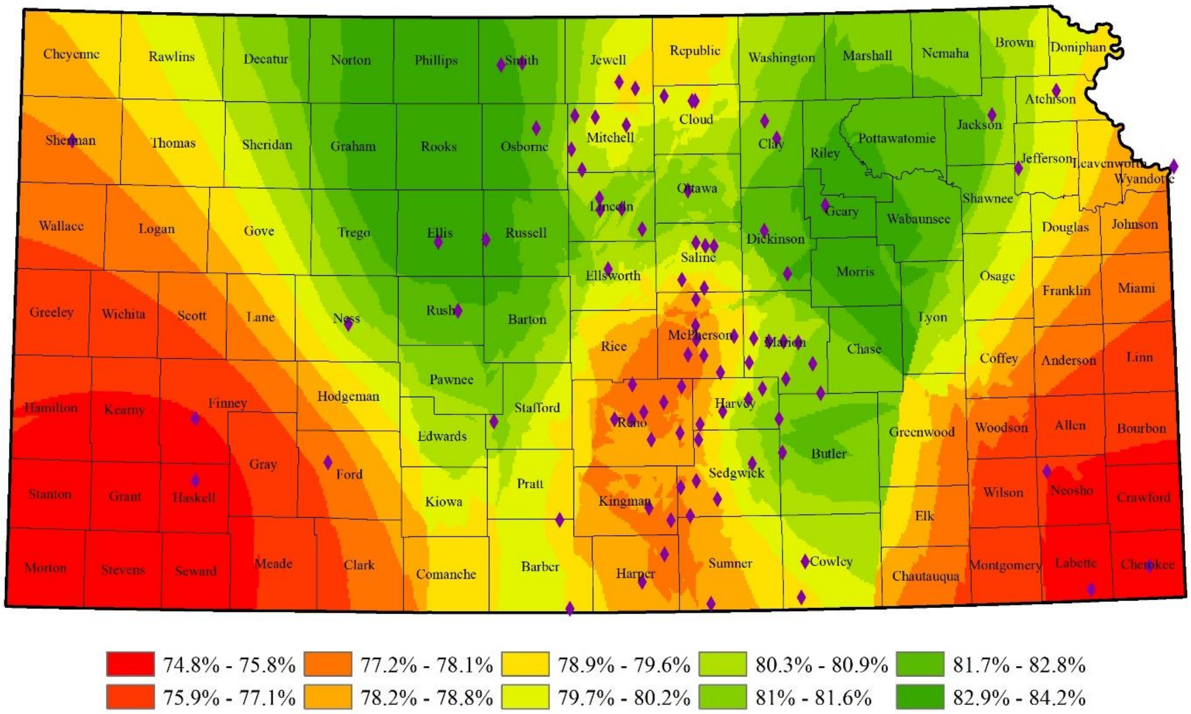
The interpolated fixed effects coefficients are shown in Figure 4.3 and are listed in Table B.2 in Appendix B. These values can be interpreted as the expected difference between basis at each location and basis at Kansas City. The fixed effects are highest around the delivery locations of Hutchinson, Wichita, Salina, and Abilene. As distance from these delivery locations increases, the fixed effects decrease. The inverse relationship between distance to a delivery location and the expected difference in basis demonstrates the theory that transportation costs to a delivery location are a major factor in determining cash prices in outlying markets.

Figure 4.3 Fixed Effects (-$0.08 basis)



The interpolated comovement coefficient is shown in Figure 4.4 and are listed in Table B.2 in Appendix B. Areas with a higher comovement coefficient would be expected to show a stronger reliance on Kansas City, the only barge loading facility in the state, as a source of basis signaling. Interestingly, the areas around the other delivery locations exhibit relatively low levels of comovement. This indicates the delivery locations in south-central Kansas may receive basis signaling from another source, most likely the Port of Catoosa in Tulsa, OK. This would also explain the low basis comovement levels in the southeast region of the state.

Figure 4.4 Basis Comovement with Kansas City (-$0.08 basis)



The interpolated effects of nonconvergence on basis are shown in Figure 4.5 and are listed in Table B.2 in Appendix B. Areas with more negative values are more sensitive to nonconvergence, indicating a weaker than expected basis relative to Kansas City during nonconvergence. Locations in the central part of the state are less susceptible to nonconvergence. This suggests that nonconvergence caused by a lack of storage in Kansas City may not translate to nonconvergence in all delivery locations. To test this hypothesis, the cooperative and noncooperative storage capacities known by the Arthur Capper Cooperative Center, were summed by county and interpolated across the state, shown in Figure 4.6 (Briggeman, Jackson, and Bilberry 2016). Storage capacity is largest in the area where nonconvergence had the least effect on basis levels, signifying that high levels of storage capacity should minimize storage availability concerns and dampen the effects of nonconvergence.

Figure 4.5 Effects of Nonconvergence (-$0.08 basis)

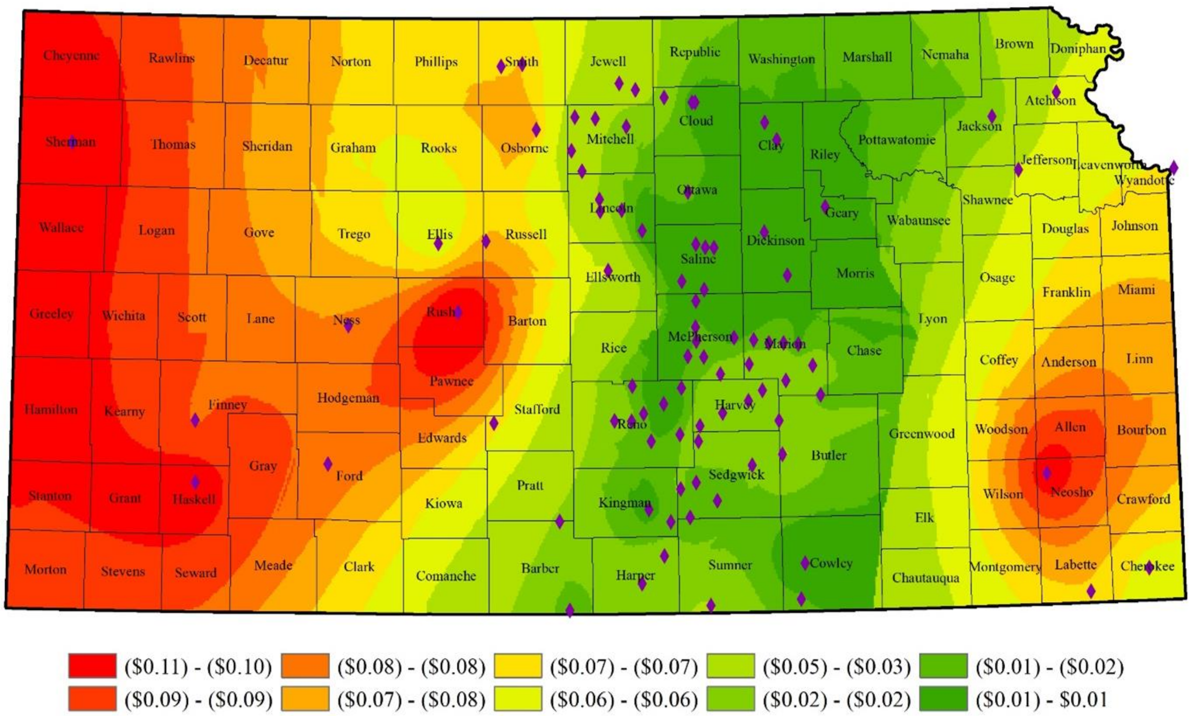
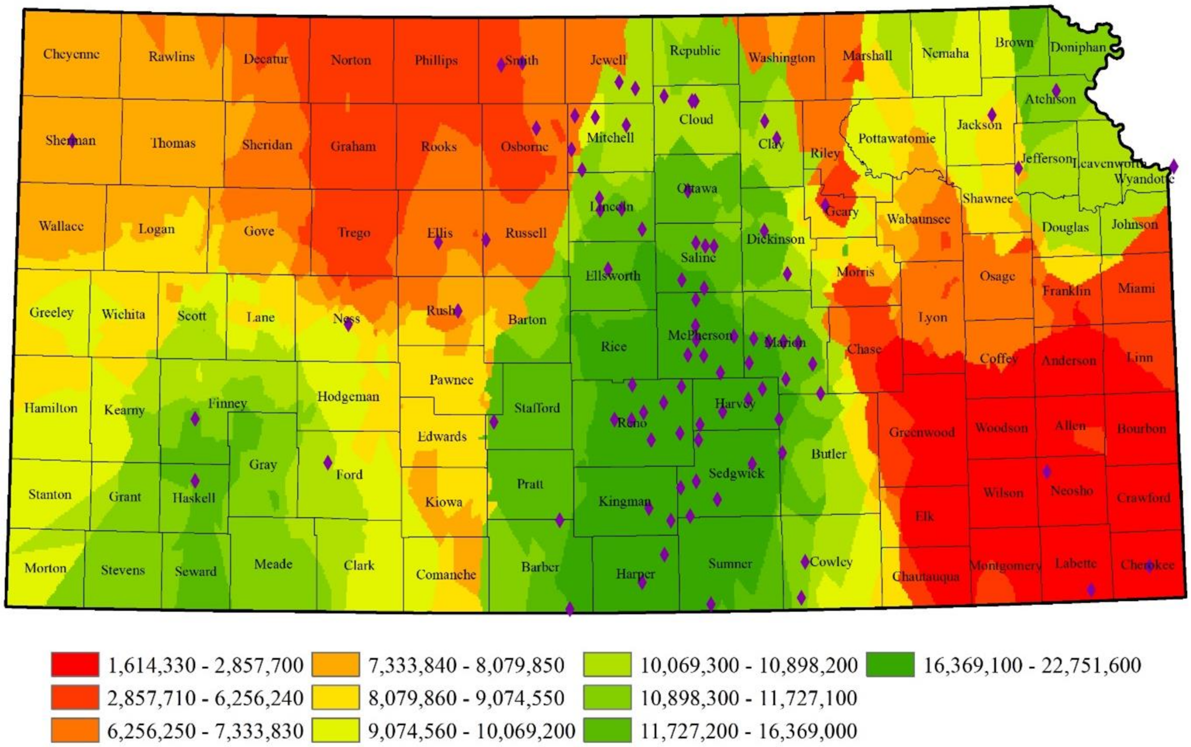


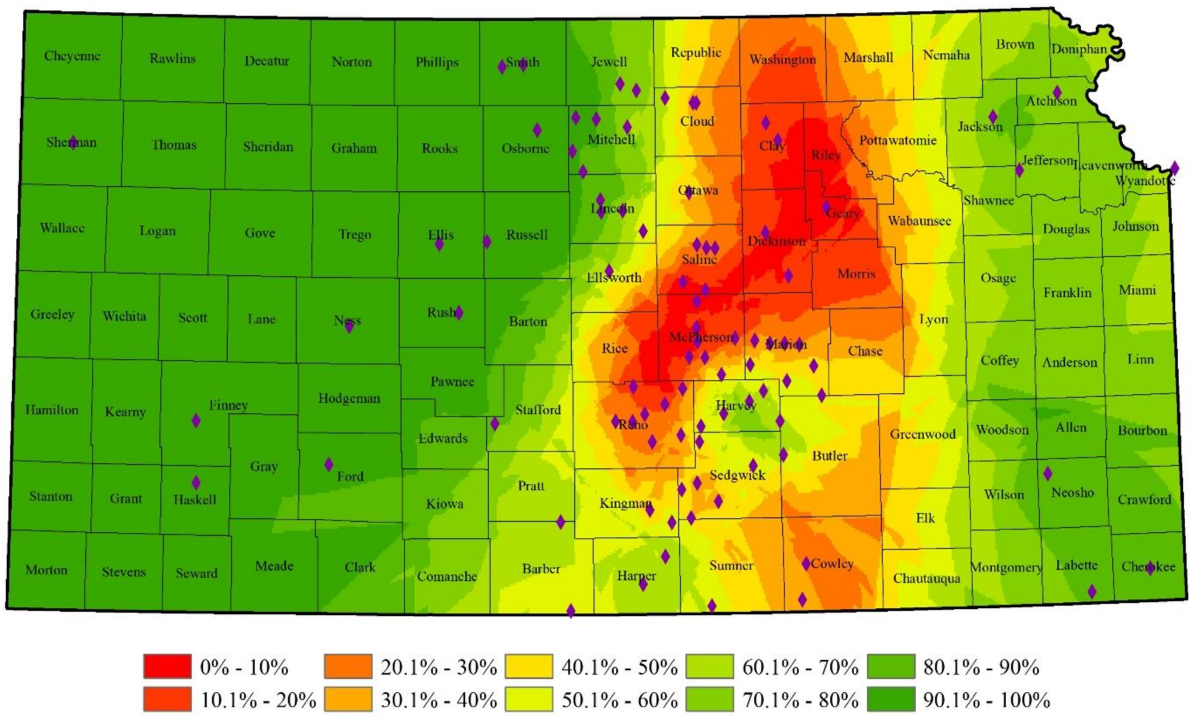
Figure 4.6 Kansas Grain Storage Capacity



Source: Briggeman et al. (2016)

A dummy variable signifying the statistical significance of the estimated effects of nonconvergence was interpolated and sorted into ten equal interval categories, shown in Figure 4.7. This map can be interpreted as the probability that nonconvergence has an effect on basis in a specific location. Nonconvergence is less likely to affect basis around the delivery locations of Salina and Hutchinson. Unsurprisingly, the areas that exhibited the lowest effect of nonconvergence were also the least likely to exhibit a statistically significant impact on basis. Areas with a low probability of significance are unlikely to observe an effect on basis attributed to nonconvergence.

Figure 4.7 Significance of the Effect of Nonconvergence (-$0.08 basis)



4.4.2 15 Cent Under Model

To test the results for sensitivity to the arbitrary definition of nonconvergence, the same model was applied to the same data; however, nonconvergence was defined to occur when the average basis during the delivery period in Kansas City was weaker than 15 cents under. Of the 76 total contracts studied, 36 were considered nonconvergent when defined this way, compared to the 44 nonconvergent contracts when defined at eight cents under. A summary of the regression results for the 15 cent under model is shown in Table 4.5, the basis seasonality coefficients are shown in Table 4.6, and the full results are shown in Table B.3 in Appendix B. The difference in the average estimated coefficients for location specific fixed effects and basis seasonality between the 15 cent under and eight cent under models is negligible; however, the estimated coefficient for basis comovement and the effect of nonconvergence change slightly.

The average basis comovement in the 15 cent under model increases by 1.9% over the 8 cent under model. The effect of nonconvergence decreases by $0.02. Moreover, only 26 of the locations exhibited significantly negative effects of nonconvergence compared to 49 of the eight cent under model. One location, a regular facility in Abilene, exhibited a significantly positive effect of nonconvergence, meaning during nonconvergence, basis strengthened relative to basis in Kansas City.

Table 4.5 Summary of Regression Results (15 cent under NC)

	Coefficients			
	Fixed Effects (FE_i)	**Contract Month (CM_j)**	**Comovement (δ_i)**	**Nonconvergence (γ_i)**
n	89	4	90	90
Mean	-0.3191	0.0281	81.69%	-0.0146
Min	-0.4419	-0.0023	67.63%	-0.1209
Max	0.0302	0.0455	93.41%	0.0386
10th Percentile	-0.3851	0.0061	77.98%	-0.0805
90th Percentile	-0.2765	0.0449	85.25%	0.0200
Counts:				
Significantly[1] >0	1	3	90	1
Significantly[1] <0	88	0	0	26
Number >0	1	3	90	43
Number <0	88	1	0	47
Prob > F = 0				
R-squared = 0.8966				

Note: [1]Significant at the 95% confidence interval.

Table 4.6 Seasonality of Basis (15 cent under NC)

Delivery Month	CM_j	
March	0.0455	***
	(0.0012)	
May	0.0436	***
	(0.0012)	
September	-0.0023	*
	(0.0013)	
December	0.0258	***
	(0.0012)	

Note: Standard errors in parenthesis

Significance levels: *** = significant at 99% CI, ** = significant at 95% CI, * = significant at 90% CI

The previously stated interpolation methods of spherical kriging and categorizing by quantiles were applied to the coefficients from the 15 cent under model.

The interpolated location specific fixed effects from the 15 cent under model are shown in Figure 4.8. The coefficients can be found in Table B.3 in Appendix B. Comparing Figure 4.8 with Figure 4.3, there appears to be no measurable difference in the spatial distribution of the fixed effects between the two models. Therefore, it can be assumed that the fixed effects coefficients are independent of the definition of nonconvergence.

Figure 4.8 Location Specific Fixed Effects (-$0.15 basis)

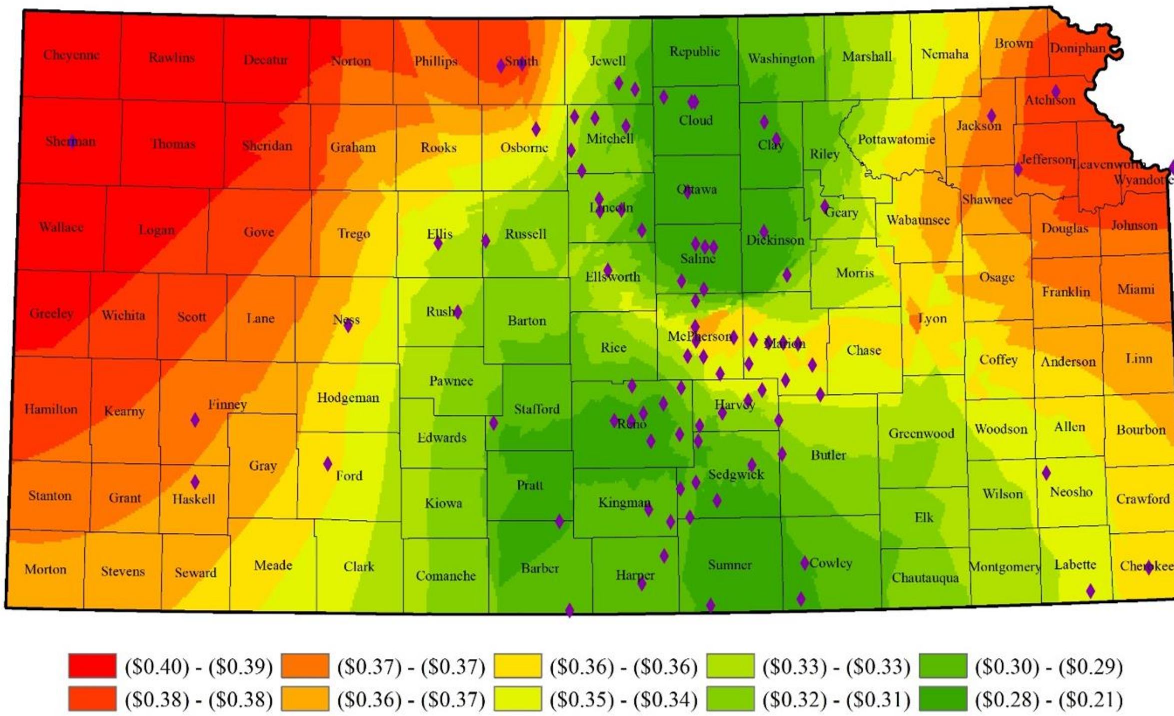


Figure 4.9 shows the interpolated comovement coefficient from the 15 cent under model and are listed in Table B.3 in Appendix B. Comparing Figure 4.9 to Figure 4.4, the spatial distribution is similar; however, the delivery locations in the south-central region display a higher basis comovement.

Figure 4.9 Basis Comovement with Kansas City (-$0.15 basis)

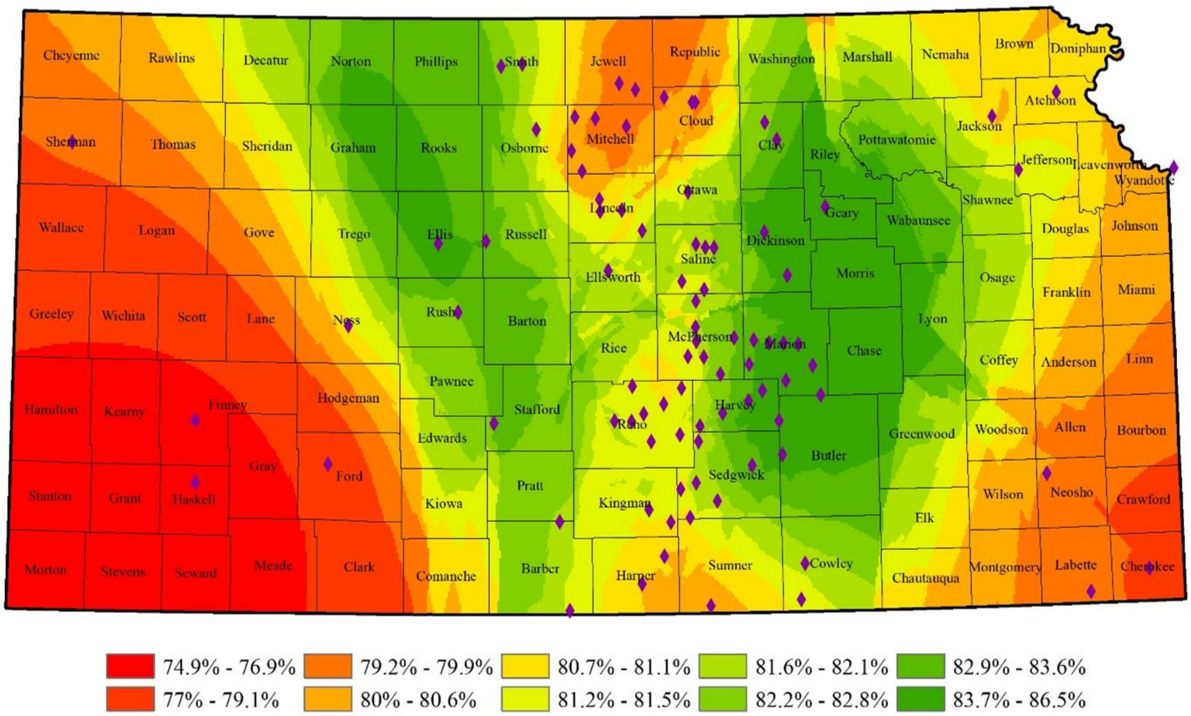


Figure 4.10 shows the interpolated effects of nonconvergence coefficients from the 15 cent under model and are listed in Table B.3 in Appendix B. There is no notable difference in the spatial distribution of the effects of nonconvergence between the two models; however, the range of the estimated coefficients is 4.75% wider for the 15 cent under model.

Figure 4.10 Effects of Nonconvergence (-$0.15 basis)

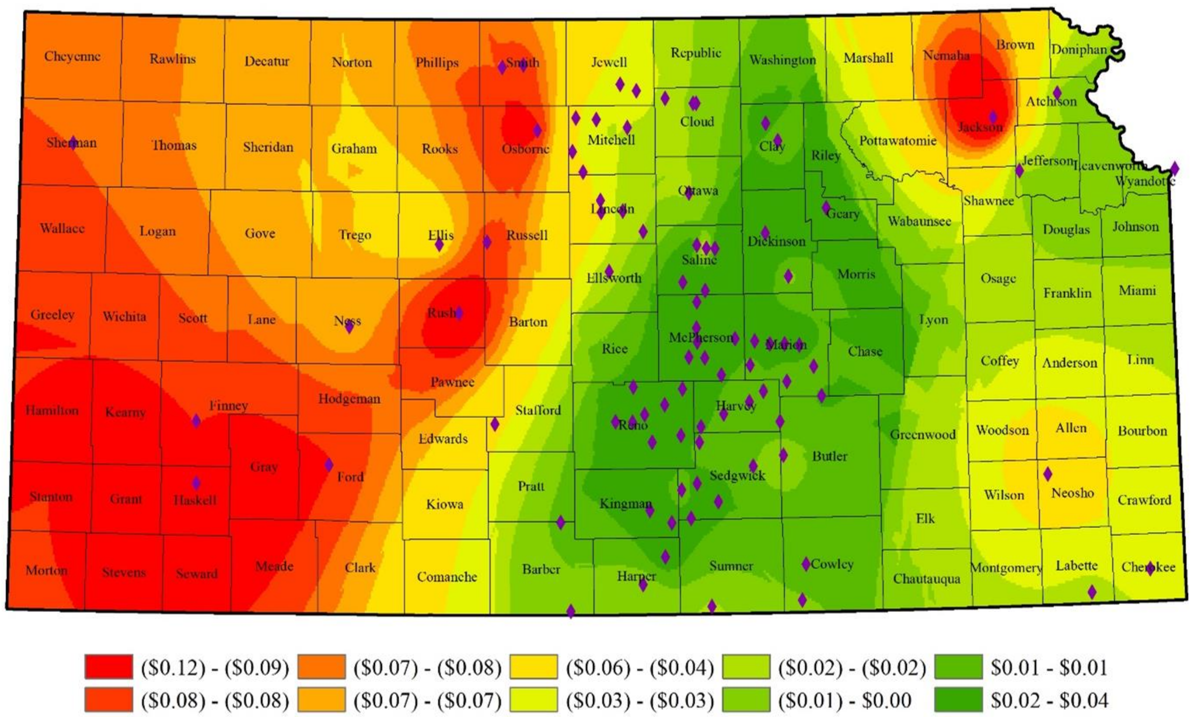
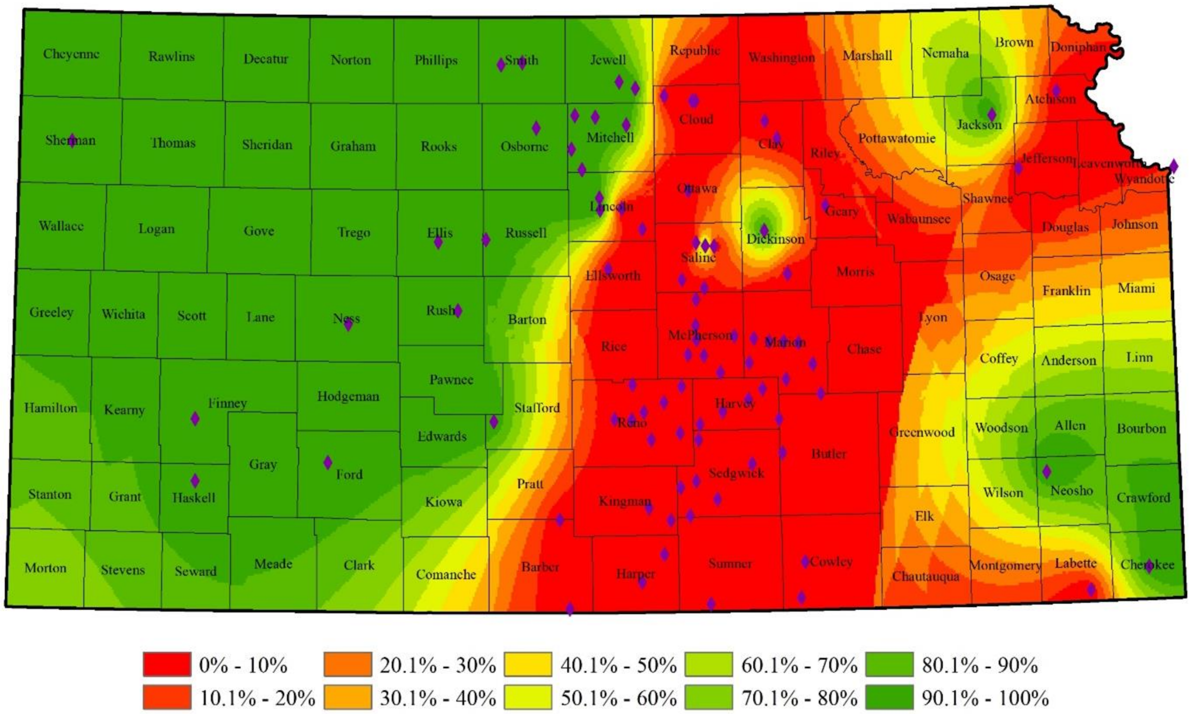


Figure 4.11 shows the interpolated significance of the effect of nonconvergence on basis for the 15 cent under model. The central corridor of the state is highly unlikely to see a significant change in basis due to nonconvergence. Compared to Figure 4.7, fewer locations are likely to exhibit any effect of nonconvergence on basis. Moreover, there is a steeper spatial gradient between locations that are likely to be affected by nonconvergence and those that are unlikely to be affected.

Figure 4.11 Significance of the Effect of Nonconvergence (-$0.15 basis)



Overall, the large similarities between the 8 cent under and 15 cent under models shows the models are not extremely sensitive to the rather arbitrary definition of nonconvergence.

4.5 Conclusion

Geospatial mapping of cross-sectional time series data demonstrated how basis patterns varied across the state. Naïve pricing allows producers to easily calculate expected changes in basis with readily available data as demonstrated in this paper. This study reaffirmed the economic theory that basis is linked to transportation costs by analyzing the location-specific fixed effects. Though this is not new information, it helps explain the price disparity between locations throughout the state. Similarly, nonconvergence has a lessened effect on basis in areas with more grain storage and locations near delivery locations. This is likely part of the explanation behind the weaker connection to Kansas City's cash prices of study locations in the southern half of the state compared to those in the northern part of the state. Geospatial analysis gives a more comprehensive understanding of the effects of nonconvergence than the stand-alone results and helps producers make more informed decisions about grain marketing.

Farm managers can use the results of this study in discussions with their producers to help them understand the historical movement of basis and trends in regards to location and delivery month. It is important for all users of both cash and futures markets to understand the underlying price and/or basis risk they may be facing. Future work should be done in this area to examine the impact of variable storage rates and the shift to shipping certificates on the hard red winter wheat market.

Chapter 5 - Summary and Conclusions

Nonconvergence threatens to devalue the use of futures markets as a risk management tool through decreased liquidity. Kansas wheat producers are especially affected by nonconvergence. Not only do they face abnormally weak basis, they are exposed to higher basis risk when using the futures market to hedge grain. Nonconvergence is theorized to be caused when the storage rate on the delivery instrument is less than the cost of storing the physical commodity. The difference between the delivery instrument's storage rate and the physical commodity's storage rate is called a wedge. A wedge causes nonconvergence in two ways. The first way is disincentivizing holders of shipping certificates from loading-out, expanding the disconnect between the cash and futures markets. The second occurs when regular facilities set a low basis in order to be compensated for the higher physical storage costs. The CBOT introduced the VSR mechanism, which adjusts the storage rate on shipping certificates based on the average percent financial full carry in the observation period, in the HRW wheat contract for the March '18 contract to alleviate convergence concerns.

This thesis examined the relationship between the average percent financial full carry in the observation period and looked at the spatial effects of nonconvergence on basis at non-delivery locations throughout the state of Kansas. Daily spot closing prices, closing futures prices, and three-month LIBOR interest rates were acquired from DTN's ProphetX database from 2004 to 2019.

After categorizing each contract month into a convergence outcome based on the average basis during the delivery period for each location, a multinomial logit model was used to show the dramatic increase in the probability of cash under futures nonconvergence in the HRW wheat contract when the average percent financial full carry in the observation period was greater than

80% at four delivery locations. The VSR will decrease the average percent financial full carry in the next contract month by increasing the cost of holding a shipping certificate, thus decreasing the probability of nonconvergence. Because the VSR adjusts storage rates, and ultimately percent financial full carry, incrementally, there exists a possibility that a large storage shock could cause periodic nonconvergence. However, the VSR should prevent long spells of nonconvergence. There was no measurable relationship between cash over futures nonconvergence and percent financial full carry, indicating the reduction in storage rates triggered when the average percent financial full carry in the observation period is under 50% will not prevent high basis levels. This may have been due to a low number of contract months that exhibited cash over futures nonconvergence in the dataset. The CBOT can use information in Chapter 3 as evidence that the underlying theory behind the VSR holds true in the HRW wheat market.

Expected basis for HRW wheat in 90 non-delivery locations in the state of Kansas was predicted using a naïve basis model and interpolated over space to examine the spatial effects of nonconvergence. Through the use of location specific fixed effects, basis was shown to be strongest near delivery locations and to weaken as the distance to a delivery location increases. Monthly dummy variables showed that basis is weakest for the July and September contracts when harvest drastically increases the local supply of grain. Changes in basis in outlying locations were shown to occur in the same direction, but at a reduced magnitude, as a change in basis in Kansas City. Basis comovement was lower in the southern half of the state, indicating a lessened dependence on Kansas City for basis signaling in these areas. Nonconvergence was found to have the smallest effect on basis near the delivery locations in the south-central region of Kansas. These regions have a higher grain storage capacity which could alleviate the stress from a lack of available physical storage. Farmers and elevator managers can utilize information in Chapter 4 when making marketing decisions and setting basis levels.

This thesis was limited by the lack of contract month observations following the implementation of the VSR. When more data are available, further research should be undertaken on the effectiveness of the VSR in preventing nonconvergence. Moreover, further research on the interaction between the VSR and the nearby spread could provide insight into how an unknown storage rate on shipping certificates affects the perceived value of the grain at a certain point in the future.

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Appendix A - Predicting the Probability of Nonconvergence

Table A.1 Full Monthly Dataset

	Average Basis in the Delivery Period				
Contract	**Kansas City**	**Hutchinson**	**Salina (Cargill)**	**Salina (Scoular)**	**Average FFC**
MAY'04	-0.0495	-0.1065	-0.0815	-0.0685	0.4304
JUL'04	0.0350	-0.1261	-0.0839	-0.0872	0.6139
SEP'04	0.0475	0.0364	0.0353	0.0208	0.7167
DEC'04	-0.1468	-0.0508	-0.0018	0.0043	0.2052
MAR'05	-0.0593	-0.1063	-0.1083	-0.1073	-0.7001
MAY'05	-0.1443	-0.0153	-0.0153	-0.0163	-0.2297
JUL'05	0.1778	-0.0333	0.0033	0.0044	0.5871
SEP'05	0.2272	0.0039	0.0317	0.0339	0.5385
DEC'05	0.1508	-0.0413	0.0922	0.1328	0.1769
MAR'06	0.0518	-0.1083	0.0388	0.0328	0.0217
MAY'06	0.0545	-0.1150	0.1235	0.0385	0.3477
JUL'06	0.0957	-0.0600	0.0038	0.0150	0.5817
SEP'06	-0.1540	0.0450	0.0830	0.0350	0.6795
DEC'06	-0.1161	-0.0439	0.0038	-0.0183	0.5312
MAR'07	-0.2375	-0.0828	0.0515	0.0585	0.5591
MAY'07	0.0289	0.1135	0.1955	0.1515	0.1089
JUL'07	-0.0500	-0.2022	-0.2033	-0.2522	0.7228
SEP'07	-0.2411	-0.2267	-0.2222	-0.2300	0.5856
DEC'07	-0.2888	-0.2890	-0.3744	-0.3744	0.2309
MAR'08	-0.3350	-0.1940	-0.3080	-0.2920	0.4276
MAY'08	-0.7550	-0.5040	-0.6430	-0.6370	0.0915
JUL'08	-0.1842	-0.2725	-0.3207	-0.3164	0.7948
SEP'08	-0.3183	-0.3204	-0.2614	-0.2600	1.0033
DEC'08	-0.3538	-0.1400	-0.1043	-0.1814	0.7946
MAR'09	-0.2856	-0.1369	-0.0831	-0.0994	0.8812
MAY'09	-0.1522	-0.1459	-0.0872	-0.0897	0.8316
JUL'09	-0.1522	-0.2456	-0.3133	-0.4500	0.8670
SEP'09	-0.6406	-0.5906	-0.5917	-0.5839	0.9859
DEC'09	-0.7930	-0.6580	-0.6280	-0.6260	0.9827
MAR'10	-0.6235	-0.6725	-0.6195	-0.6135	1.0246
MAY'10	-0.5919	-0.7615	-0.7886	-0.8125	1.0383
JUL'10	-0.8469	-0.9136	-1.1536	-1.0547	1.0362
SEP'10	-0.8586	-0.7419	-0.7875	-0.8053	0.8951
DEC'10	-0.7269	-0.6550	-0.6930	-1.0080	0.8531
MAR'11	-0.7173	-0.5523	-0.6413	-0.7583	0.7970
MAY'11	-0.6854	-0.5515	-0.6525	-0.6072	0.8614
JUL'11	0.0103	-0.1181	-0.1536	-0.1092	1.4854
SEP'11	-0.3061	-0.1536	-0.2247	-0.2231	1.3580

	Average Basis in the Delivery Period				
Contract	Kansas City	Hutchinson	Salina (Cargill)	Salina (Scoular)	Average FFC
DEC'11	-0.1743	0.0050	-0.0063	0.0142	0.4452
MAR'12	-0.2160	0.1210	0.0560	0.0580	0.5471
MAY'12	-0.2355	-0.1525	-0.2625	-0.2495	0.6097
JUL'12	0.0263	-0.1953	-0.1997	-0.2064	1.0214
SEP'12	-0.2478	-0.1456	-0.2300	-0.2032	0.6746
DEC'12	-0.2850	-0.1175	-0.1215	-0.1203	0.4521
MAR'13	-0.3103	-0.0393	-0.0913	-0.1339	0.6866
MAY'13	-0.1808	-0.0953	-0.0768	-0.0600	0.3295
JUL'13	0.0511	-0.0200	-0.1544	-0.1591	0.3826
SEP'13	-0.0775	-0.1686	-0.1919	-0.1714	0.2452
DEC'13	-0.0320	-0.1410	-0.1880	-0.2121	0.0197
MAR'14	0.0565	-0.1255	-0.2095	---	-0.2475
MAY'14	-0.0425	-0.0625	-0.0915	-0.0794	0.2073
JUL'14	-0.0072	-0.0394	-0.1172	-0.0745	0.3030
SEP'14	-0.0339	-0.1350	-0.2339	-0.2196	0.4339
DEC'14	-0.0358	-0.0648	-0.0748	-0.0797	0.0901
MAR'15	0.0668	-0.0833	0.0468	-0.1700	0.2574
MAY'15	0.0685	-0.0315	-0.1315	-0.1245	0.3408
JUL'15	0.1792	0.0892	0.0558	0.0203	0.6849
SEP'15	-0.1619	-0.0544	-0.1044	-0.1289	0.6779
DEC'15	-0.1985	-0.2005	-0.2505	-0.2935	0.4969
MAR'16	-0.1193	-0.2913	-0.3413	-0.3423	0.6965
MAY'16	-0.1198	-0.4018	-0.4518	---	0.7899
JUL'16	-0.3178	-0.7267	-0.7044	-0.6978	1.1778
SEP'16	-0.5619	-0.9008	-0.8508	-0.8975	0.8744
DEC'16	-0.6080	-0.8210	-0.8730	-0.8930	0.5815
MAR'17	-0.4206	-0.7615	-0.8015	-0.8395	0.8575
MAY'17	-0.3275	-0.5905	-0.5355	-0.5855	0.8618
JUL'17	-0.2450	-0.7169	-0.7281	-0.7247	1.2480
SEP'17	-0.4428	-0.7517	-0.7517	-0.7950	0.8930
DEC'17	-0.1053	-0.2223	-0.2253	-0.3403	0.5851
MAR'18	0.0228	-0.1273	-0.1773	-0.2313	0.9543
MAY'18	0.0025	-0.0785	-0.1555	-0.2105	0.9390
JUL'18	0.4736	0.1736	0.1236	0.1769	0.6337
SEP'18	0.2725	-0.1286	-0.1786	-0.1219	0.6922
DEC'18	0.2814	0.1158	0.0658	0.0075	0.6351

Appendix B - Basis Expectations During Nonconvergence

Table B.1 Summary of Daily Data

Location	# of Obs	Mean	St. Dev	High	Low
Abbyville	3288	-0.4559	0.3253	0.2325	-1.3450
Anthony	3324	-0.4636	0.3112	0.2850	-1.3450
Ark City	3163	-0.4462	0.3126	0.2850	-1.9700
Assaria	3242	-0.5437	0.3417	0.0050	-1.6475
Athol	3311	-0.6521	0.3454	-0.0325	-1.9975
Bartlett	3167	-0.5484	0.3340	0.0000	-1.4550
Benton	3243	-0.4899	0.3320	0.2075	-1.3900
Buhler	3245	-0.5015	0.3301	0.0275	-1.6475
Burns	3245	-0.5478	0.3399	0.0575	-1.6475
Burrton	3246	-0.4922	0.3281	0.1675	-1.3925
Caldwell	3294	-0.4447	0.3128	0.2850	-1.3450
Chanute	3318	-0.4940	0.3339	0.0575	-1.3500
Cheney	3308	-0.4510	0.3086	0.2475	-1.3250
Columbus	3282	-0.5391	0.3295	0.0050	-1.4750
Conway	3235	-0.5246	0.3241	0.0075	-1.4025
Dodge City	3208	-0.5751	0.3248	0.0275	-1.7550
Ellsworth	3311	-0.5446	0.3432	0.1475	-1.6000
Falun	3242	-0.5596	0.3447	-0.0050	-1.4525
Florence	3245	-0.5450	0.3418	0.0575	-1.4625
Garden City	3121	-0.5566	0.3153	0.0275	-1.5000
Garden Plain	3302	-0.4502	0.3079	0.2475	-1.3250
Goessel	3242	-0.5211	0.3315	0.0875	-1.6000
Goodland	3185	-0.6006	0.3296	0.0600	-1.6075
Halstead	3244	-0.4943	0.3286	0.1675	-1.4025
Haven	3246	-0.4748	0.3289	0.1575	-1.4225
Hays	3366	-0.5356	0.3538	0.2725	-1.9000
Hillsboro	3243	-0.5219	0.3375	0.0675	-1.4225
Hutchinson - Cargill	3295	-0.2770	0.3102	0.2850	-1.2500
Hutchinson - Whiteside	3244	-0.4503	0.3269	0.1175	-1.3525
Hutchinson - MKC	3245	-0.4713	0.3250	0.1675	-1.3725
Inman	3243	-0.5043	0.3240	0.0175	-1.3725
Isabel	3298	-0.4447	0.3182	0.2175	-1.4100
Junction City	3302	-0.5541	0.3470	0.1350	-1.6200
Kingman	3302	-0.4560	0.3129	0.2275	-1.3250
Kiowa	3310	-0.4724	0.3236	0.2850	-1.3850
Lehigh	3244	-0.5269	0.3359	0.0575	-1.4125
Lindsborg	3230	-0.5457	0.3376	-0.0050	-1.4425
Marion	3245	-0.5339	0.3415	0.0475	-1.6875
Marion - Canada	3245	-0.5097	0.3341	0.0675	-1.4025
Mcpherson - Hilton	3245	-0.5290	0.3293	0.0075	-1.8875
Mcpherson	3246	-0.5154	0.3278	0.0075	-1.4025
Mcpherson - Elyria	3243	-0.5312	0.3273	0.0375	-1.4100
Milton	3305	-0.4565	0.3152	0.2475	-2.0600
Morganville	3294	-0.5190	0.3285	0.2400	-1.5600
Moundridge	3245	-0.5155	0.3308	0.1275	-1.4125
Mount Hope	3244	-0.4806	0.3254	0.1875	-1.3800
Newton	3246	-0.5134	0.3431	0.0875	-1.4525
Nickerson	3246	-0.4621	0.3288	0.0775	-1.3625
Norwich	3306	-0.4591	0.3106	0.2475	-1.4225
Osborne	3269	-0.6316	0.3493	-0.0200	-1.7100

Location	# of Obs	Mean	St. Dev	High	Low
Partridge	3245	-0.4535	0.3288	0.1075	-1.3625
Peabody	3247	-0.5252	0.3406	0.0775	-1.5475
Salina - Cargill	3324	-0.2915	0.3230	0.2550	-1.4575
Smith Center	3294	-0.6536	0.3452	-0.0325	-1.7300
Viola	3291	-0.4440	0.3072	0.2475	-1.3700
Walton	3247	-0.5107	0.3365	0.0875	-1.4325
Whitewater	3244	-0.5134	0.3372	0.1375	-1.4325
Wichita	3231	-0.3815	0.3435	0.2475	-1.2825
Winfield	3257	-0.4384	0.3104	0.2475	-1.4675
Kansas City MO	3219	-0.2284	0.3224	0.5175	-1.8075
Holton	1748	-0.5435	0.3753	0.0575	-1.5825
Meriden	3251	-0.6044	0.3317	0.0575	-1.5750
Lancaster	3236	-0.5988	0.3225	0.4625	-1.5750
Bison	3080	-0.5485	0.3484	0.0775	-1.5000
Canton	3144	-0.5306	0.3307	0.0775	-1.4025
Danville	2932	-0.4598	0.3125	0.2475	-1.6500
Gorham	3030	-0.5140	0.3576	0.2100	-1.4800
Hope	3005	-0.4932	0.3263	0.1150	-2.0800
Macksville	3047	-0.4917	0.3716	0.1675	-2.3000
Minneapolis	3094	-0.4965	0.3346	0.2000	-1.6750
Salina - Scoular	3125	-0.3194	0.3640	0.8025	-2.5500
Sublette	3105	-0.5696	0.3213	0.0425	-1.9050
Abilene	3149	-0.3204	0.3334	0.4800	-1.7950
Salina - ADM	3106	-0.1177	0.2973	1.1150	-1.3725
Ness City	3158	-0.5952	0.3537	0.0775	-1.5050
Clay Center	3139	-0.5016	0.3242	0.0300	-1.8500
Concordia - East	3097	-0.3602	0.3258	0.2400	-1.7000
Concordia	3060	-0.3616	0.3282	0.2400	-1.7000
Jamestown	3098	-0.4698	0.3305	0.0800	-1.8200
Jewell	3105	-0.5144	0.3252	0.0300	-1.8500
Randall	3106	-0.5105	0.3295	-0.0100	-1.8500
Denmark	3088	-0.5135	0.3375	0.0700	-1.8800
Lincoln	3108	-0.4662	0.3279	0.0400	-1.8000
Vesper	3111	-0.5136	0.3307	0.0200	-1.8300
Hunter	3108	-0.4896	0.3292	0.0700	-1.8500
Westfall	3099	-0.4901	0.3299	0.0400	-1.8600
Beloit	3105	-0.4917	0.3319	0.0800	-1.8700
Cawker City	3093	-0.4698	0.3316	0.1000	-1.8500
Glen Elder	3107	-0.4419	0.3180	0.0700	-1.8000
Tipton	3106	-0.4873	0.3277	0.0200	-1.8500
Futures Price	3383	5.642788	1.7016	13.3700	3.1175

Table B.2 Regression Results (8 cent under NC)

Location	Fixed Effects		Comovement		Nonconvergence	
Abbyville	-0.2863	***	0.7876	***	-0.0265	**
	(0.0039)		(0.0240)		(0.0122)	
Anthony	-0.2962	***	0.7748	***	-0.0297	**
	(0.0035)		(0.0241)		(0.0120)	
Ark City	-0.2846	***	0.7826	***	-0.0190	*
	(0.0037)		(0.0231)		(0.0113)	
Assaria	-0.3792	***	0.7915	***	-0.0106	
	(0.0047)		(0.0261)		(0.0134)	
Athol	-0.4399	***	0.8471	***	-0.0763	***
	(0.0038)		(0.0220)		(0.0108)	
Bartlett	-0.3518	***	0.7475	***	-0.0772	***
	(0.0044)		(0.0238)		(0.0127)	
Benton	-0.3052	***	0.8199	***	-0.0342	***
	(0.0039)		(0.0241)		(0.0119)	
Buhler	-0.3365	***	0.7740	***	-0.0190	
	(0.0043)		(0.0250)		(0.0127)	
Burns	-0.3712	***	0.8163	***	-0.0216	*
	(0.0042)		(0.0255)		(0.0128)	
Burrton	-0.3176	***	0.7899	***	-0.0284	**
	(0.0039)		(0.0245)		(0.0123)	
Caldwell	-0.2761	***	0.7801	***	-0.0335	***
	(0.0035)		(0.0241)		(0.0120)	
Chanute	-0.2937	***	0.7339	***	-0.1016	***
	(0.0038)		(0.0231)		(0.0120)	
Cheney	-0.2879	***	0.7644	***	-0.0249	**
	(0.0035)		(0.0236)		(0.0118)	
Columbus	-0.3637	***	0.7404	***	-0.0678	***
	(0.0040)		(0.0244)		(0.0124)	
Conway	-0.3610	***	0.7724	***	-0.0185	
	(0.0041)		(0.0244)		(0.0123)	
Dodge City	-0.3800	***	0.7570	***	-0.0884	***
	(0.0040)		(0.0221)		(0.0108)	
Ellsworth	-0.3479	***	0.8233	***	-0.0569	***
	(0.0037)		(0.0236)		(0.0122)	
Falun	-0.3944	***	0.7929	***	-0.0122	
	(0.0048)		(0.0263)		(0.0136)	
Florence	-0.3620	***	0.8233	***	-0.0297	**
	(0.0042)		(0.0255)		(0.0127)	
Garden City	-0.3725	***	0.7505	***	-0.0897	***
	(0.0041)		(0.0241)		(0.0111)	
Garden Plain	-0.2888	***	0.7708	***	-0.0202	*
	(0.0034)		(0.0222)		(0.0109)	
Goessel	-0.3441	***	0.8010	***	-0.0291	**
	(0.0039)		(0.0248)		(0.0123)	
Goodland	-0.3984	***	0.7791	***	-0.1022	***
	(0.0043)		(0.0219)		(0.0099)	
Halstead	-0.3175	***	0.7892	***	-0.0332	***
	(0.0039)		(0.0245)		(0.0123)	
Haven	-0.3023	***	0.7951	***	-0.0227	*
	(0.0040)		(0.0249)		(0.0124)	
Hays	-0.3268	***	0.8714	***	-0.0618	***
	(0.0037)		(0.0231)		(0.0114)	
Hillsboro	-0.3491	***	0.8020	***	-0.0213	

Location	Fixed Effects		Comovement		Nonconvergence	
	(0.0043)		(0.0256)		(0.0130)	
Hutchinson - Cargill	-0.1299	***	0.7574	***	-0.0002	
	(0.0036)		(0.0238)		(0.0119)	
Hutchinson - Whiteside	-0.2835	***	0.7728	***	-0.0226	*
	(0.0042)		(0.0247)		(0.0125)	
Hutchinson - Mkc	-0.3000	***	0.7992	***	-0.0190	
	(0.0039)		(0.0244)		(0.0122)	
Inman	-0.3419	***	0.7688	***	-0.0170	
	(0.0041)		(0.0246)		(0.0125)	
Isabel	-0.2738	***	0.7772	***	-0.0307	***
	(0.0036)		(0.0230)		(0.0112)	
Junction City	-0.3676	***	0.9017	***	-0.0076	
	(0.0038)		(0.0246)		(0.0122)	
Kingman	-0.2923	***	0.7958	***	-0.0140	
	(0.0034)		(0.0220)		(0.0110)	
Kiowa	-0.3000	***	0.8198	***	-0.0202	*
	(0.0036)		(0.0229)		(0.0115)	
Lehigh	-0.3544	***	0.8037	***	-0.0194	
	(0.0042)		(0.0254)		(0.0128)	
Lindsborg	-0.3819	***	0.7992	***	-0.0082	
	(0.0045)		(0.0258)		(0.0132)	
Marion	-0.3599	***	0.8168	***	-0.0166	
	(0.0043)		(0.0259)		(0.0131)	
Marion - Canada	-0.3369	***	0.7942	***	-0.0242	*
	(0.0042)		(0.0252)		(0.0127)	
Mcpherson - Hilton	-0.3618	***	0.7802	***	-0.0199	
	(0.0041)		(0.0250)		(0.0126)	
Mcpherson	-0.3500	***	0.7726	***	-0.0197	
	(0.0042)		(0.0247)		(0.0126)	
Mcpherson - Elyria	-0.3639	***	0.7806	***	-0.0202	
	(0.0040)		(0.0246)		(0.0125)	
Milton	-0.2918	***	0.7910	***	-0.0177	
	(0.0034)		(0.0232)		(0.0113)	
Morganville	-0.3528	***	0.8035	***	-0.0169	
	(0.0039)		(0.0238)		(0.0121)	
Moundridge	-0.3412	***	0.7939	***	-0.0269	**
	(0.0039)		(0.0249)		(0.0125)	
Mount Hope	-0.3062	***	0.7942	***	-0.0270	**
	(0.0039)		(0.0243)		(0.0121)	
Newton	-0.3328	***	0.8139	***	-0.0290	**
	(0.0043)		(0.0258)		(0.0129)	
Nickerson	-0.2936	***	0.7790	***	-0.0223	*
	(0.0043)		(0.0246)		(0.0125)	
Norwich	-0.2940	***	0.7820	***	-0.0221	**
	(0.0034)		(0.0222)		(0.0109)	
Osborne	-0.4185	***	0.8435	***	-0.0820	***
	(0.0038)		(0.0225)		(0.0112)	
Partridge	-0.2862	***	0.7715	***	-0.0234	*
	(0.0042)		(0.0247)		(0.0126)	
Peabody	-0.3438	***	0.8133	***	-0.0310	**
	(0.0042)		(0.0255)		(0.0127)	
Salina - Cargill	-0.1357	***	0.8011	***	0.0044	
	(0.0042)		(0.0241)		(0.0120)	
Smith Center	-0.4402	***	0.8419	***	-0.0788	***
	(0.0038)		(0.0223)		(0.0109)	

Location	Fixed Effects		Comovement		Nonconvergence	
Viola	-0.2834	***	0.7686	***	-0.0207	*
	(0.0035)		(0.0221)		(0.0109)	
Walton	-0.3365	***	0.8015	***	-0.0231	*
	(0.0042)		(0.0252)		(0.0127)	
Whitewater	-0.3342	***	0.8138	***	-0.0272	**
	(0.0041)		(0.0252)		(0.0126)	
Wichita	-0.1957	***	0.8460	***	-0.0236	*
	(0.0042)		(0.0251)		(0.0125)	
Winfield	-0.2835	***	0.8109	***	-0.0094	
	(0.0034)		(0.0221)		(0.0104)	
Kansas City Mo	N/A	N/A	0.9052	***	-0.0725	***
	N/A		(0.0200)		(0.0072)	
Holton	-0.3610	***	0.8355	***	-0.0240	**
	(0.0055)		(0.0238)		(0.0121)	
Meriden	-0.4105	***	0.8043	***	-0.0568	***
	(0.0047)		(0.0204)		(0.0105)	
Lancaster	-0.4135	***	0.7786	***	-0.0574	***
	(0.0046)		(0.0203)		(0.0104)	
Bison	-0.3184	***	0.8017	***	-0.1123	***
	(0.0040)		(0.0234)		(0.0114)	
Canton	-0.3581	***	0.7923	***	-0.0153	
	(0.0041)		(0.0253)		(0.0129)	
Danville	-0.3055	***	0.7581	***	-0.0269	**
	(0.0034)		(0.0225)		(0.0115)	
Gorham	-0.2961	***	0.8548	***	-0.0804	***
	(0.0040)		(0.0247)		(0.0124)	
Hope	-0.3366	***	0.8026	***	-0.0148	
	(0.0039)		(0.0251)		(0.0125)	
Macksville	-0.2722	***	0.8345	***	-0.0749	***
	(0.0049)		(0.0256)		(0.0125)	
Minneapolis	-0.3059	***	0.8611	***	-0.0236	**
	(0.0037)		(0.0208)		(0.0100)	
Salina - Scoular	-0.1423	***	0.8900	***	0.0152	
	(0.0044)		(0.0275)		(0.0122)	
Sublette	-0.3684	***	0.7184	***	-0.1006	***
	(0.0041)		(0.0219)		(0.0108)	
Abilene	-0.1517	***	0.8312	***	0.0056	
	(0.0042)		(0.0262)		(0.0131)	
Salina	0.0248	***	0.6949	***	-0.0276	***
	(0.0041)		(0.0183)		(0.0099)	
Ness City	-0.3801	***	0.8178	***	-0.0862	***
	(0.0043)		(0.0239)		(0.0116)	
Clay Center	-0.3387	***	0.7916	***	-0.0170	
	(0.0038)		(0.0241)		(0.0120)	
Concordia - East	-0.1985	***	0.7879	***	-0.0137	
	(0.0043)		(0.0245)		(0.0124)	
Concordia	-0.1987	***	0.7906	***	-0.0147	
	(0.0043)		(0.0247)		(0.0126)	
Jamestown	-0.2972	***	0.7934	***	-0.0301	**
	(0.0041)		(0.0240)		(0.0122)	
Jewell	-0.3408	***	0.7732	***	-0.0405	***
	(0.0038)		(0.0238)		(0.0119)	
Randall	-0.3341	***	0.7863	***	-0.0396	***
	(0.0039)		(0.0241)		(0.0121)	
Denmark	-0.3330	***	0.8327	***	-0.0320	**

Location	Fixed Effects		Comovement		Nonconvergence	
	(0.0040)		(0.0252)		(0.0125)	
Lincoln	-0.2971	***	0.7912	***	-0.0246	**
	(0.0041)		(0.0243)		(0.0122)	
Vesper	-0.3366	***	0.7903	***	-0.0390	***
	(0.0041)		(0.0244)		(0.0123)	
Hunter	-0.3087	***	0.7963	***	-0.0438	***
	(0.0040)		(0.0237)		(0.0118)	
Westfall	-0.3197	***	0.8250	***	-0.0126	
	(0.0041)		(0.0246)		(0.0123)	
Beloit	-0.3158	***	0.8217	***	-0.0240	*
	(0.0040)		(0.0244)		(0.0122)	
Cawker City	-0.2844	***	0.8210	***	-0.0445	***
	(0.0036)		(0.0242)		(0.0117)	
Glen Elder	-0.2666	***	0.7743	***	-0.0426	***
	(0.0036)		(0.0228)		(0.0112)	
Tipton	-0.3084	***	0.7952	***	-0.0411	***
	(0.0040)		(0.0237)		(0.0117)	

Note: Standard errors in parenthesis

Significance levels: *** = significant at 1% CI, ** = significant at 5% CI, * = significant at 10% CI

Table B.3 Regression Results (15 cent under NC)

Location	Fixed Effects		Comovement		Nonconvergence	
Abbyville	-0.2943	***	0.8293	***	0.0152	
	(0.0037)		(0.0257)		(0.0132)	
Anthony	-0.2982	***	0.7888	***	-0.0145	
	(0.0032)		(0.0250)		(0.0126)	
Ark City	-0.2854	***	0.7949	***	-0.0055	
	(0.0035)		(0.0238)		(0.0118)	
Assaria	-0.3848	***	0.8284	***	0.0265	*
	(0.0046)		(0.0278)		(0.0145)	
Athol	-0.4419	***	0.8403	***	-0.0805	***
	(0.0036)		(0.0213)		(0.0105)	
Bartlett	-0.3674	***	0.7993	***	-0.0244	*
	(0.0048)		(0.0251)		(0.0131)	
Benton	-0.3097	***	0.8425	***	-0.0105	
	(0.0037)		(0.0249)		(0.0124)	
Buhler	-0.3421	***	0.8074	***	0.0149	
	(0.0042)		(0.0266)		(0.0137)	
Burns	-0.3763	***	0.8466	***	0.0094	
	(0.0040)		(0.0266)		(0.0135)	
Burrton	-0.3249	***	0.8269	***	0.0092	
	(0.0037)		(0.0259)		(0.0132)	
Caldwell	-0.2783	***	0.7927	***	-0.0192	
	(0.0032)		(0.0251)		(0.0127)	
Chanute	-0.3097	***	0.7779	***	-0.0563	***
	(0.0041)		(0.0249)		(0.0129)	
Cheney	-0.2928	***	0.7928	***	0.0040	
	(0.0033)		(0.0251)		(0.0127)	
Columbus	-0.3736	***	0.7729	***	-0.0345	***
	(0.0045)		(0.0256)		(0.0131)	
Conway	-0.3677	***	0.8104	***	0.0200	
	(0.0040)		(0.0261)		(0.0135)	
Dodge City	-0.3839	***	0.7531	***	-0.0895	***
	(0.0036)		(0.0215)		(0.0105)	
Ellsworth	-0.3567	***	0.8546	***	-0.0245	*
	(0.0035)		(0.0247)		(0.0130)	
Falun	-0.4003	***	0.8308	***	0.0259	*
	(0.0048)		(0.0279)		(0.0146)	
Florence	-0.3673	***	0.8510	***	-0.0011	
	(0.0041)		(0.0266)		(0.0135)	
Garden City	-0.3770	***	0.7501	***	-0.0883	***
	(0.0036)		(0.0235)		(0.0108)	
Garden Plain	-0.2933	***	0.7997	***	0.0088	
	(0.0032)		(0.0234)		(0.0117)	
Goessel	-0.3502	***	0.8323	***	0.0030	
	(0.0038)		(0.0261)		(0.0132)	
Goodland	-0.4086	***	0.7999	***	-0.0807	***
	(0.0038)		(0.0221)		(0.0100)	
Halstead	-0.3252	***	0.8260	***	0.0043	
	(0.0037)		(0.0259)		(0.0131)	
Haven	-0.3084	***	0.8291	***	0.0119	
	(0.0038)		(0.0261)		(0.0132)	
Hays	-0.3289	***	0.8711	***	-0.0600	***
	(0.0034)		(0.0229)		(0.0116)	
Hillsboro	-0.3562	***	0.8408	***	0.0178	

Location	Fixed Effects		Comovement		Nonconvergence	
	(0.0041)		(0.0272)		(0.0139)	
Hutchinson - Cargill	-0.1280	***	0.7665	***	0.0097	
	(0.0033)		(0.0246)		(0.0129)	
Hutchinson - Whiteside	-0.2906	***	0.8114	***	0.0164	
	(0.0040)		(0.0262)		(0.0135)	
Hutchinson - MKC	-0.3047	***	0.8289	***	0.0113	
	(0.0037)		(0.0254)		(0.0128)	
Inman	-0.3481	***	0.8059	***	0.0205	
	(0.0040)		(0.0263)		(0.0136)	
Isabel	-0.2799	***	0.8084	***	0.0011	
	(0.0032)		(0.0240)		(0.0120)	
Junction City	-0.3716	***	0.9341	***	0.0249	*
	(0.0037)		(0.0259)		(0.0130)	
Kingman	-0.2963	***	0.8257	***	0.0158	
	(0.0032)		(0.0232)		(0.0117)	
Kiowa	-0.3004	***	0.8303	***	-0.0086	
	(0.0034)		(0.0235)		(0.0120)	
Lehigh	-0.3608	***	0.8402	***	0.0175	
	(0.0040)		(0.0270)		(0.0138)	
Lindsborg	-0.3866	***	0.8333	***	0.0263	*
	(0.0044)		(0.0273)		(0.0142)	
Marion	-0.3657	***	0.8523	***	0.0194	
	(0.0042)		(0.0273)		(0.0140)	
Marion - Canada	-0.3441	***	0.8322	***	0.0142	
	(0.0040)		(0.0268)		(0.0137)	
Mcpherson - Hilton	-0.3689	***	0.8197	***	0.0200	
	(0.0040)		(0.0267)		(0.0138)	
Mcpherson	-0.3569	***	0.8115	***	0.0196	
	(0.0040)		(0.0266)		(0.0138)	
Mcpherson - Elyria	-0.3705	***	0.8176	***	0.0172	
	(0.0039)		(0.0262)		(0.0135)	
Milton	-0.2956	***	0.8179	***	0.0093	
	(0.0033)		(0.0243)		(0.0120)	
Morganville	-0.3577	***	0.8356	***	0.0155	
	(0.0037)		(0.0246)		(0.0127)	
Moundridge	-0.3483	***	0.8305	***	0.0102	
	(0.0038)		(0.0264)		(0.0134)	
Mount Hope	-0.3120	***	0.8252	***	0.0048	
	(0.0037)		(0.0253)		(0.0127)	
Newton	-0.3381	***	0.8418	***	-0.0002	
	(0.0041)		(0.0270)		(0.0137)	
Nickerson	-0.2993	***	0.8115	***	0.0109	
	(0.0041)		(0.0260)		(0.0134)	
Norwich	-0.2989	***	0.8117	***	0.0077	
	(0.0032)		(0.0234)		(0.0117)	
Osborne	-0.4200	***	0.8302	***	-0.0921	***
	(0.0036)		(0.0217)		(0.0109)	
Partridge	-0.2937	***	0.8114	***	0.0169	
	(0.0041)		(0.0264)		(0.0136)	
Peabody	-0.3495	***	0.8420	***	-0.0014	
	(0.0041)		(0.0266)		(0.0135)	
Salina - Cargill	-0.1330	***	0.8083	***	0.0125	
	(0.0039)		(0.0244)		(0.0124)	
Smith Center	-0.4416	***	0.8312	***	-0.0866	***
	(0.0036)		(0.0214)		(0.0105)	

Location	Fixed Effects		Comovement		Nonconvergence	
Viola	-0.2890	***	0.8022	***	0.0127	
	(0.0033)		(0.0234)		(0.0117)	
Walton	-0.3421	***	0.8329	***	0.0090	
	(0.0041)		(0.0264)		(0.0135)	
Whitewater	-0.3397	***	0.8431	***	0.0029	
	(0.0039)		(0.0263)		(0.0133)	
Wichita	-0.1985	***	0.8650	***	-0.0036	
	(0.0040)		(0.0258)		(0.0130)	
Winfield	-0.2833	***	0.8240	***	0.0041	
	(0.0033)		(0.0228)		(0.0109)	
Kansas City MO	#N/A	#N/A	0.9178	***	-0.0643	***
	#N/A		(0.0199)		(0.0078)	
Holton	-0.3371	***	0.7422	***	-0.1209	***
	(0.0049)		(0.0228)		(0.0126)	
Meriden	-0.4207	***	0.8431	***	-0.0175	*
	(0.0049)		(0.0203)		(0.0098)	
Lancaster	-0.4242	***	0.8196	***	-0.0164	*
	(0.0049)		(0.0201)		(0.0097)	
Bison	-0.3267	***	0.8019	***	-0.1084	***
	(0.0037)		(0.0235)		(0.0116)	
Canton	-0.3643	***	0.8289	***	0.0220	
	(0.0039)		(0.0270)		(0.0140)	
Danville	-0.3138	***	0.8045	***	0.0194	
	(0.0033)		(0.0249)		(0.0130)	
Gorham	-0.2984	***	0.8474	***	-0.0847	***
	(0.0036)		(0.0246)		(0.0127)	
Hope	-0.3350	***	0.8083	***	-0.0081	
	(0.0037)		(0.0259)		(0.0135)	
Macksville	-0.2817	***	0.8591	***	-0.0477	***
	(0.0044)		(0.0266)		(0.0132)	
Minneapolis	-0.3053	***	0.8652	***	-0.0179	*
	(0.0035)		(0.0207)		(0.0102)	
Salina - Scoular	-0.1381	***	0.8958	***	0.0217	*
	(0.0041)		(0.0271)		(0.0123)	
Sublette	-0.3728	***	0.7110	***	-0.1045	***
	(0.0036)		(0.0213)		(0.0106)	
Abilene	-0.1548	***	0.8640	***	0.0386	***
	(0.0039)		(0.0273)		(0.0137)	
Salina - ADM	0.0302	***	0.6763	***	-0.0442	***
	(0.0037)		(0.0185)		(0.0106)	
Ness City	-0.3875	***	0.8318	***	-0.0700	***
	(0.0039)		(0.0241)		(0.0118)	
Clay Center	-0.3388	***	0.8023	***	-0.0050	
	(0.0037)		(0.0261)		(0.0135)	
Concordia - East	-0.1945	***	0.7822	***	-0.0172	
	(0.0041)		(0.0257)		(0.0134)	
Concordia	-0.1958	***	0.7894	***	-0.0140	
	(0.0042)		(0.0259)		(0.0136)	
Jamestown	-0.2968	***	0.7959	***	-0.0249	*
	(0.0039)		(0.0257)		(0.0134)	
Jewell	-0.3416	***	0.7757	***	-0.0347	***
	(0.0037)		(0.0254)		(0.0132)	
Randall	-0.3340	***	0.7852	***	-0.0372	***
	(0.0038)		(0.0255)		(0.0133)	
Denmark	-0.3302	***	0.8233	***	-0.0378	***

Location	Fixed Effects		Comovement		Nonconvergence	
	(0.0039)		(0.0264)		(0.0136)	
Lincoln	-0.2959	***	0.7922	***	-0.0212	
	(0.0040)		(0.0259)		(0.0135)	
Vesper	-0.3344	***	0.7800	***	-0.0452	***
	(0.0040)		(0.0255)		(0.0133)	
Hunter	-0.3076	***	0.7890	***	-0.0469	***
	(0.0038)		(0.0250)		(0.0129)	
Westfall	-0.3151	***	0.8168	***	-0.0184	
	(0.0039)		(0.0257)		(0.0132)	
Beloit	-0.3125	***	0.8141	***	-0.0287	**
	(0.0038)		(0.0255)		(0.0132)	
Cawker City	-0.2834	***	0.8143	***	-0.0470	***
	(0.0034)		(0.0254)		(0.0128)	
Glen Elder	-0.2693	***	0.7845	***	-0.0295	**
	(0.0034)		(0.0246)		(0.0125)	
Tipton	-0.3072	***	0.7886	***	-0.0437	***
	(0.0038)		(0.0249)		(0.0128)	

Note: Standard errors in parenthesis

Significance levels: *** = significant at 1% CI, ** = significant at 5% CI, * = significant at 10% CI