Competing for Wheat in the Great Plains: Impacts of Shuttle - Loading Grain Facilities on Basis Patterns

by

Anton Bekkerman, Mykel Taylor, Gage Ridder, and Brian Briggeman

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Highly competitive grain commodity markets create incentives for grain handling companies to employ a variety of strategies for reducing variable cost margins. Shuttle-loading elevators—high-capacity, high-speed grain loading facilities—are a relatively recent example of grain companies adopting technologies that improve efficiency, allow them to take advantage of improved rail rates and guaranteed car availability, and attract grain suppliers from further distances. The ability to load shuttle-unit trains within a designated amount of time enables elevators to preferentially reserve rail cars and, in many cases, more consistently meet the volume and timing needs of foreign buyers than elevators without shuttle-loading technologies. This comparative advantage has spurred upgrading existing elevators or building new shuttle-loading facilities across the Great Plains (Bekkerman, 2013).

If shuttle-loading facilities reduce the marginal costs of handling a bushel of grain, then it seems plausible that some portion of those savings will be passed on to grain producers in the form of stronger basis bids (i.e., higher cash prices). Increased demand for grain by elevators with shuttle-loaders is also likely to contribute to local basis improvements, because these facilities must attract a sufficient volume of grain from surrounding areas to fill the shuttle-unit trains they have reserved. In crop years with low production due to unexpected negative supply events, such as drought, hail, or other inhospitable growing conditions, shuttle-loaders' effect on basis strength is expected to be more pronounced.

The objective of this study is to measure systematic impacts on local wheat basis in Kansas and Montana, two states where there has been substantial growth in the number of shuttle-loading elevators, from the existence of the high-speed grain handling facilities. We use an extensive dataset of daily basis bids at grain elevators during 2004–2013 to model cross-sectional and temporal variation in the basis and identify differences that can be attributed alternative loading technologies. Specifically, weekly basis bids are modeled as a function of local supply and demand factors, elevator-specific characteristics, futures market information, and unobserved heterogeneity that may affect elevators' grain bids (Taylor, Tonsor, and Dhuyvetter, 2013). Furthermore, we find presence of spatial dependence in basis bids across elevator locations, resulting from farmers' abilities to arbitrage away price differences that exist among competing grain handling facilities. The empirical specification accounts for such spatial autocorrelation. The estimation results indicate that basis bids are, on average, 1.3 cents higher than at conventional elevators. However, there are differences in basis bids at shuttle-loading facilities across the two states, with basis being 1.2 cents higher in Kansas and 3.2 cents higher in Montana. This suggests that while basis premiums may be consistently observed at shuttle-loading elevators, heterogeneity in market structures across major grain production can also have important implications for understanding the behavior and more accurately predicting basis bids.

Overview of Relevant Literature

Knowledge about basis is important to both farmers and grain merchandizers, helping inform them of market information regarding returns to storage, downstream and local demand, and changing

costs of transportation. Accurately predicting basis can, therefore, help reduce risk exposure, develop efficient marketing strategies, and hedge variability in grain prices. Many previous studies of basis behavior have focused on two related areas: improving basis prediction and determining factors that help explain variation in basis.

Local basis behavior has typically been categorized as having intertemporal and spatial determinants as well as being affected by changes in public policy and the marketing environment. Intertemporal costs are comprised of the carrying costs of storing grain, which include storage costs (on-farm and commercial), demand for grain (e.g. flow), and interest costs of holding grain rather than selling it. A thorough review of the theory underlying the intertemporal impacts on basis can be found in Garcia and Good (1983). Aside from the intertemporal relationships, a number of studies demonstrated that wheat basis can be affected by changes in the market structure, including adjustments to loan deficiency payments, introduction of ethanol plants, unanticipated variation in protein content of grain produced in a particular region, and increased transportation costs (Dykema, Klein, and Taylor, 2002; Martin, Groenewegen, and Pigeon, 1980; Jiang and Hayenga, 1997).

The literature has paid less attention, however, to the theory of spatial factors, which is likely due to the general consensus that spatial differences in basis are driven by variation in transportation costs (Strobl, Fortenbery, and Fackler 1992). However, other research suggests there may be significant impacts on basis from local demand centers, such as ethanol plants in certain areas of the country (McNew and Griffith 2005). This more recent research suggests that demand-side factors associated with differences in grain delivery facilities could also be important determinants of spatial variation in basis bids.

The question of whether or not transportation cost savings incurred by elevators with the capability of loading shuttle (unit) trains has been transferred to farmers has been previously addressed in the literature. Fortenbery, Zapata, and Kunda (1993) analyzed corn basis during the period from 1980 to 1992 in order to understand the impacts of the 1980 Staggers Act, which deregulated the rail road industry and greatly impacted grain shipping through changes in freight rates. One result of the deregulation was an increase in the number of shuttle train loader facilities, which could now take advantage of lower freight rates. Using harvest time basis levels at 16 Corn Belt locations, the authors estimated a spatio-temporal error component model that used elevator concentration measures to determine whether grain companies were able to capture decreased transportation savings rather than passing them on to farmers. The results indicated no adverse price impacts from deregulation and that basis improvements (i.e., higher cash prices to farmers) were found for some locations where there was relatively little elevator concentration prior to deregulation.

Hauser, Jeffrey, and Baumel (1984) determined that the impacts of shuttle train loading facilities on basis in Iowa were different from those in Nebraska. In Iowa, the marketing landscape was relatively saturated with large capacity 25- and 50-car loading facilities prior to the Staggers Act deregulation, while Nebraska had relatively few of these facilities and presented greater entry opportunities. A mathematical programming model used to estimate the implicit (shadow) prices of shuttle train loader facilities indicated that shadow prices were larger for Nebraska than Iowa, suggesting greater cost savings benefits to grain companies, and possible improvements in local basis, were likely to occur in areas with fewer existing shuttle train loading facilities.

Data and Preliminary Insights

To quantify the impacts of shuttle loader elevators on winter wheat basis levels, a panel dataset of daily cash and futures prices was assembled for 297 locations in Kansas and Montana from 2004 to 2013. The cash prices were obtained from the DTN historical database for all the elevators in Kansas and for the majority of elevators and days in Montana. The remaining prices for Montana were obtained from Cash Grain Bids, Inc. Cash prices represent hard red winter wheat with a protein content of 11% for Kansas and ordinary (10% or less), 11%, 12%, and 13% protein content for Montana wheat. Montana grain prices were averaged across the protein levels to calculate a single winter wheat price for each day and elevator.[1] Reporting of cash prices to both data sources is not mandatory, so several locations without consistent price reporting were removed from the dataset.[2] For the remaining locations, less than 0.3% of cash price data were missing and were interpolated to ensure temporal consistency of the data. All interpolated observations were cross-validated to ensure that interpolation models did not overfit the data.[3]

Futures prices for the nearby (closest contract to expiration at a given point in time) and harvest (July) hard red winter wheat contracts traded on the Kansas City Board of Trade (KCBT), as well as implied volatilities for the nearby contracts were collected from Bloomberg.[4] For both the cash and futures prices, the weekly price represents the cash bid or settle price for trading on Wednesdays. From the cash and futures prices, the nearby and harvest basis levels were calculated by subtracting the futures price from the cash price.

Additional information about the elevators in the panel dataset was gathered from a variety of sources. The ability of an elevator to load shuttle trains was determined by directly contacting individual elevators and from state and federal elevator licensing records, railroad websites, news releases, and the Kansas Grain and Feed Association's Annual Directory. For each elevator reported to be a shuttle loader, the year in which they began loading shuttle trains was also recorded. Other elevator characteristics were similarly collected and include information about rail line access, business structure (cooperative or investor-owned firms), and licensed grain holding capacity. Table 1 presents the summary statistics of the panel dataset.

The locations of all the Kansas elevators in the in panel are presented in figure 1. Shuttle loader elevators are presented in red, while the conventional elevators are blue. The size of the circles

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[1] While DTN historical databases only report prices for 11%, 12%, and 13% protein level winter wheat marketed in Montana, Cash Grain Bids, Inc. report prices for these protein levels and the ordinary protein level. Because elevators discount lower protein content wheat, the average price is expected to be higher when the ordinary protein level wheat price is excluded. However, the difference is expected to be relatively constant across time and elevators within a common marketing environment (Bekkerman, unpublished data representing Montana elevator protein discount schedules for 22 locations in 2011–2013) and can be accounted for using an indicator variable in an empirical specification.

[2] Systematic differences were not detected between locations that were removed and locations that remained in the dataset.

[3] Cross-validation guards against overfitting by using continuous out-of-sample forecast accuracy measures: one observation from the data is iteratively omitted, and a fitted model is used to predict the omitted data point.

[4] The roll date for the nearby contract was defined as the first day of the month that the nearby contract was due to expire. The roll date for the harvest contract was defined as the 15th day of the month in which the July harvest contract expired.

marking each elevator correspond to their licensed grain storage capacity. The lines on the map represent rail lines in the state. While all the elevators are located near the rail lines, not every elevator is built close enough have rail side access.[5] The location, relative capacity, and rail lines in Montana are also presented in figure 1.

Visual comparisons of the two maps reveal a higher density of elevators in the state of Kansas, as well as more rail lines. Summary statistics of select variables, by state and shuttle loading capacity, are presented in table 2. While Montana has fewer numbers of elevators, as compared to Kansas, the proportion of shuttle loaders to conventional elevators is higher. For both states, the grain storage capacity of shuttle loaders averages five times more than conventional elevators Other differences between the two states include an average capacity in Kansas that is 2.5 times larger than Montana, but a similar proportion of elevators having rail side access with 69 and 73 percent, respectively, for Kansas and Montana.

Modeling Strategy

We model the variation in nearby basis, b_{it}, at elevator i in weekday t as follows:

$$b_{it} = \beta_0 + \beta_1(Shuttle_{it}) + \beta_2 b_{i,t-5} + \beta_3 b_{i,t-365} + \beta_4(bVolWeek_{it}) + \beta_5(ImpVolKCBT_t) + \beta_6 DTN_{it} + \delta_{month} + \delta_{year} + \delta_{county} + \varepsilon_{it} \, ,$$

where variable $Shuttle_{it}$ is a binary variable that indicates whether elevator i has shuttle-loading capabilities, $b_{i,t-5}$ is observed nearby basis level from the preceding week, $b_{i,t-365}$ is the observed nearby basis level from the preceding year (which occurred on the weekday corresponding to day t), $bVolWeek_{it}$ represents the volatility of nearby basis level in the preceding week as measured by the standard deviation of basis in the previous five business days, $ImpVolKCBT_t$ is the implied volatility of the nearby Kansas City Board of Trade winter wheat futures contract, DTN_{it} is a binary variable that indicates whether the cash price data were obtained from the DTN historical database or Cash Grain Bids, Inc., δ_{month} and δ_{year} are categorical variables that represent unobserved seasonal heterogeneity in production and marketing conditions that affect all elevator locations within a year and market environments that differ across years, and δ_{county} are categorical group variables that control for unobservable location-based heterogeneity that might be correlated with other explanatory variables.[6]

Following Baltagi (2005), the regression disturbance term, $\varepsilon_{it} = \mu + \eta_t$, is assumed to be composed of a random elevator location effect, $\mu' = (\mu_1, \dots, \mu_n) \sim N(0, \sigma_\mu^2)$, and a spatially autocorrelated factor, $\eta_t = \theta W \eta_t + v_t$. The term W represents an $n \times n$ spatial weighting matrix, θ is a scalar spatial autoregressive coefficient that satisfies the condition $|\theta| < 1$, and $v_t' = (v_{ti}, \dots, v_{tn})$ is an idiosyncratic error vector whose elements v_{ti} are assumed to be independent of μ_i.

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[5] Rail side access refers to an elevator built close enough to the rail line that grain can be loaded directly from storage into a rail car.

[6] While there are sufficient data to estimate elevator-level time-independent effects, these will be highly correlated with the indicator for whether the elevator has shuttle loading technology. Controlling for county-level effects provides an opportunity to identify the basis differences at shuttle-loading facilities.

Estimation Methods and Empirical Results

Our empirical analysis has three components. First, we estimate a random effects GLS model of nearby basis with clustered heteroskedasticity-robust standard errors, but without accounting for potential spatial autocorrelation. In part, the random effects model is chosen because the variable of interest, the shuttle loader indicator, has little variation over time at any particular elevator location, implying that traditional fixed effects models may significantly overestimate the standard errors (Wooldridge, 2003). Next, the residuals from this regression are used to test for spatial autocorrelation that may persist even after controlling for a number of observable variables and time- and location-constant unobservable effects. We estimate empirical semi-variogram functions using the residuals to identify evidence of long-run spatial dependence among nearby winter wheat basis bids. Upon determining visual and statistical evidence of spatial autocorrelation, we estimate a random effects GLS model that accounts for spatial autocorrelation.

Random Effects Model without Accounting for Spatial Autocorrelation

Table 3 presents the results from the random effects model of nearby basis across both states and for the entire sample period. All of the estimated parameters are statistically different from zero at the 1% significance level and have the expected signs. The variable of interest, the shuttle loader indicator, indicates that, on average, shuttle-loading facilities offer a 1.4 cent premium relative to conventional elevators. This suggests that shuttle loaders are able and willing to offer higher cash prices to increase incentives for greater grain delivery to those locations.

In addition to using the overall data, we estimate two sets of subsample regressions: separate estimations for each state and for periods before and including 2008 and after 2008. Table 3 presents the results of these four subsample regressions. First, these results indicate that shuttle loading facilities in Montana have a higher average premium (3.2 cents per bushel) relative to conventional facilities than those in Kansas (1.2 cents). This may indicate that, as shown by Hauser, Jeffrey, and Baumel (1983), there can be significant differences in the opportunities for shuttle loading facilities in different regions. That is, because Kansas has a substantially higher number of elevators, premiums offered by shuttle loading facilities are arbitraged away to a greater degree.

Previous research has shown that recent increases in the volatility of cash and futures markets, may affect elevator basis bids (Taylor, Tonsor, and Dhuyvetter 2013). Table 3 shows that across the two-period subsamples, premiums in Kansas shuttle loading facilities have remained the same, between 1.4 and 1.6 cents per bushel. However, Montana premiums increased from 2.4 cents per bushel before 2008 to 5.3 cents per bushel in the period after 2008. This could indicate an ability of shuttle loading facilities to withstand the greater market uncertainty that has characterized the early 2010s and offer higher prices to farmers. In Kansas, this is not the case, perhaps because of the higher competition among elevators and a greater ability for farmers to arbitrage away price differences.

Spatial Autocorrelation Analysis

Residuals from the random effects estimation are used to examine the potential spatial dependence properties across elevator locations. Because it is unlikely that nearby basis at Kansas elevators will be spatially correlated with those in Montana, we consider spatial properties in each state separately. We first examine spatial autocorrelation properties using a semi-variogram analysis, which considers the difference between nearby basis at elevators that are located near one another. If smaller differences in nearby basis are systematically identified at elevators that are closer together, and if those differences dissipate with distance, then this would suggest that estimators that do not account for this spatial autocorrelation are inefficient.

Typically, semi-variograms are used to identify spatial autocorrelation within cross-sectional data. Due to the lengthy panel data of these data, accounting for the temporal component is also important. We do this by estimating the empirical semi-variogram for elevator locations in each day and then average these semi-variogram statistics to estimate a single representation that is conditional on any temporal dynamics that may have occurred. Figures 2 and 3 show two different characterizations of the spatial autocorrelation analysis. Figure 2 presents the estimated semi-variogram, which can be considered as an indicator of nearby basis differences as a function of distance separating any two elevators, such that smaller differences for elevators that are closer together imply stronger spatial autocorrelation. Figure 3 shows a pseudo-covariance representation (the inverse semi-variogram), which provides a similarity measure—there is evidence of spatial correlation if the relationship between nearby basis is higher at elevators that are closer together.

Both figures show that there is evidence of spatial autocorrelation in nearby basis at Kansas and Montana elevators. The dependence structure exhibits classic asymptotic behavior of relatively high spatial dependence for elevators that are closer to one another and a dissipation of this relationship for elevators that are farther apart. Moreover, results of the Moran's I and Geary's C tests of spatial autocorrelation strongly reject the null hypothesis of no spatial autocorrelation in both states. The visual and statistical analyses of spatial dependence indicate the need to account for this aspect.

Random Effects Model Accounting for Spatial Autocorrelation

We re-estimated the overall, state, and period subsample regressions described above using a GLS random effects estimator that controls for spatial autocorrelation. Ideally, the spatial weighting matrix, W, in the model's error component term, $\eta_t = \theta W \eta_t + \nu_t$, would be a function of the spatial relationships (typically distances) between individual elevator locations. Due to both the large cross-sectional aspect of the data (297 elevator locations) and the extensive time-series attribute (ten years of daily data), the estimation of the covariance matrix was computationally challenging. As a result, we used county-level centroids as spatial identifiers to construct the spatial weighting matrix (there are 89 county-level locations in Kansas and 28 in Montana). While this certainly reduces the precision to which we are able to control for the spatial autocorrelation among elevators, it offers an improvement over models that ignore the spatial component.

Table 4 presents the results of the estimated random effects models that account for spatial autocorrelation. As expected, the estimated coefficients are nearly identical, but there are some

changes to the estimated standard errors. This implies that the spatial autocorrelation affected the estimator efficiency, when the dependence remains unaccounted.

Conclusion

A more complete understanding of how changes in the efficiency of grain handling affect elevators' willingness to bid for grain facilitates several practical outcomes. First, grain producers can increase their understanding of relative basis bid behaviors by shuttle-loading and conventional grain facilities, thereby improving their awareness of grain supply conditions that facilitate a competitive advantage. Second, results from this research can help identify spatio-temporal factors affecting basis patterns in response to changing conditions in Great Plains wheat markets.

Results from the models of nearby basis suggest two impacts from the existence of shuttle loading elevators. The first is an improvement in basis bids (i.e. higher cash prices to farmers) from shuttle loaders relative to conventional elevators. The estimated impact is higher in Montana at 3.2 cents per bushel than in Kansas with 1.2 cents per bushel stronger basis bids. This result is consistent previous research that showed the entry of shuttle loading elevators does not adversely affect basis bids and improves basis in some regions, as well as regional differences in basis impacts due to elevator concentration (Fortenbery, Zapata, and Kunda 1993; Hauser, Jeffrey, and Baumel 1984).

Comparisons of the changes in basis bids across two time periods (up to and including 2008 and after 2008) indicate that shuttle loaders in Montana have improved their basis bids from an average of 1.2 cents per bushel to 5.3 cents per bushel between the two time periods. Basis bids from Kansas elevators did not change appreciably, moving from an average of 1.4 cents per bushel to 1.6 cents per bushel. Future work will include expanding the scope of the basis models to further control for spatial dependence and exploit spatio-temporal effects associated with the expanded influence of shuttle-train loading facilities.

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Table 1. Summary statistics of variables in panel dataset

Variable	Variable Definition	Mean	Standard Deviation	Minimum	Maximum
KS	Binary variable indicating an elevator is located in Kansas if equal to 1	0.92	0.27	0.00	1.00
MT	Binary variable indicating an elevator is located in Montana if equal to 1	0.08	0.27	0.00	1.00
Shuttle	Binary variable indicating an elevator can load shuttle trains if equal to 1	0.09	0.29	0.00	1.00
Rail	Binary variable indicating an elevator with rail side access if equal to 1	0.69	0.46	0.00	1.00
Co-op	Binary variable indicating an elevator is owned by a cooperative if equal to 1	0.60	0.49	0.00	1.00
Capacity	Total elevator storage capacity (thousand bushels)	1,716.76	3,188.86	92.00	42,500.00
Federal	Binary variable indicating an elevator holds a federal grain storage license if equal to 1	0.47	0.50	0.00	1.00
State	Binary variable indicating an elevator holds a state grain storage license if equal to 1	0.53	0.50	0.00	1.00
NB	Nearby basis level using closest futures contract to expiration ($/bu)	-0.58	0.38	-3.27	8.46
HB	Harvest basis level using July futures contract to expiration ($/bu)	-0.58	0.57	-3.18	9.21
IV	Implied volatility from KCBT hard red winter wheat contract	32.89	7.79	0.00	68.07

Table 2. Summary statistics of select variables by state and shuttle loading capacity

Variable	Mean	Standard Deviation
Kansas		
KS	0.92	0.27
Shuttle	0.08	0.27
Rail	0.69	0.46
Co-op	0.64	0.48
Capacity (thousand bu)	1,817.12	3,535.88
Montana		
MT	0.08	0.27
Shuttle	0.23	0.43
Rail	0.73	0.44
Co-op	0.57	0.50
Capacity (thousand bu)	715.87	479.62
Shuttle Loader Elevators		
Rail	1.00	0.00
Co-op	0.29	0.46
Capacity (thousand bu)	6,309.14	9,429.94
Non-Shuttle Loader Elevators		
Rail	0.66	0.47
Co-op	0.67	0.47
Capacity (thousand bu)	1,226.74	1,073.77

Table 3. Estimation Results of Random Effects Models of Nearby Basis

	Overall	State Subsamples		Period Subsamples			
		KS	MT	KS		MT	
				Pre-2008	Post-2008	Pre-2008	Post-2008
Intercept	-0.104	-0.048	-0.142	-0.131	-0.058	-0.144	-0.201
	(0.003)	(0.002)	(0.017)	(0.003)	(0.002)	(0.030)	(0.026)
Shuttle Loader	0.013	0.013	0.032	0.017	0.014	0.024	0.052
	(0.001)	(0.001)	(0.004)	(0.001)	(0.001)	(0.008)	(0.005)
Lagged Basis, 1 year	-0.012	-0.023	-0.005	0.018	-0.032	-0.029	-0.008
	(0.001)	(0.001)	(0.003)	(0.002)	(0.001)	(0.011)	(0.003)
Lagged Basis, 1 week	0.872	0.875	0.803	0.756	0.885	0.804	0.731
	(0.001)	(0.001)	(0.003)	(0.002)	(0.001)	(0.006)	(0.004)
Basis Volatility, 1 week	-0.040	-0.057	-0.017	-0.144	-0.029	0.231	-0.227
	(0.003)	(0.003)	(0.012)	(0.005)	(0.004)	(0.025)	(0.014)
KCBT Implied Volatility	-0.001	-0.001	-0.003	-0.001	-2E-04	-0.001	-0.005
	(3E-05)	(3E-05)	(2E-04)	(3E-05)	(4E-05)	(4E-04)	(3E-04)
DTN Indicator	0.067	--	0.125	--	--	0.085	0.202
	(0.001)	--	(0.004)	--	--	(0.009)	(0.005)

Note: Monthly, annual, and county categorical control are included in all the models presented in this table.

Table 4. Estimation Results of Random Effects Models of Nearby Basis with Spatial Autocorrelation Adjustment

	Overall	State Subsamples		Period Subsamples			
		KS	*MT*	*KS*		*MT*	
				Pre-2008	Post-2008	Pre-2008	Post-2008
Intercept	-0.095	-0.054	-0.142	-0.136	-0.066	-0.112	-0.201
	-0.006	-0.016	-0.017	-0.006	-0.021	-0.056	-0.026
Shuttle Loader	0.014	0.013	0.032	0.017	0.014	0.027	0.052
	-0.001	-0.001	-0.004	-0.001	-0.001	-0.007	-0.005
Lagged Basis, 1 year	-0.012	-0.023	-0.005	0.017	-0.032	-0.031	-0.008
	-0.001	-0.001	-0.003	-0.002	-0.001	-0.011	-0.003
Lagged Basis, 1 week	0.872	0.875	0.803	0.756	0.885	0.804	0.731
	-0.001	-0.001	-0.003	-0.002	-0.001	-0.006	-0.004
Basis Volatility, 1 week	-0.04	-0.056	-0.017	-0.144	-0.029	0.23	-0.227
	-0.003	-0.003	-0.012	-0.005	-0.004	-0.025	-0.014
KCBT Implied Volatility	-0.001	-0.001	-0.003	-0.001	-2E-04	-0.001	-0.005
	(3E-05)	(3E-05)	(2E-04)	(3E-05)	(4E-05)	(4E-04)	(3E-04)
DTN Indicator	0.067	--	0.125	--	--	0.083	0.202
	-0.001	--	-0.004	--	--	-0.009	-0.005

Note: Monthly, annual, and county categorical control are included in all the models presented in this table.
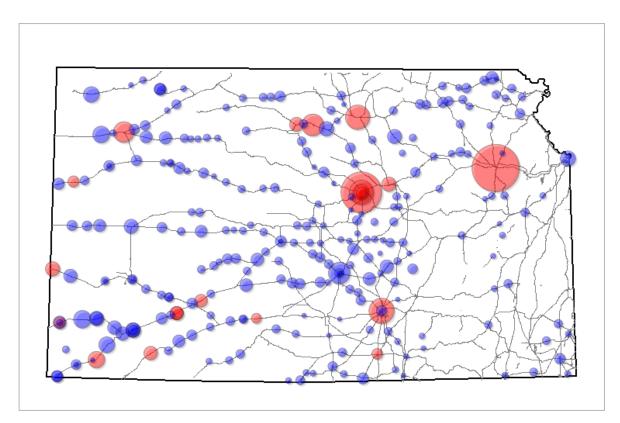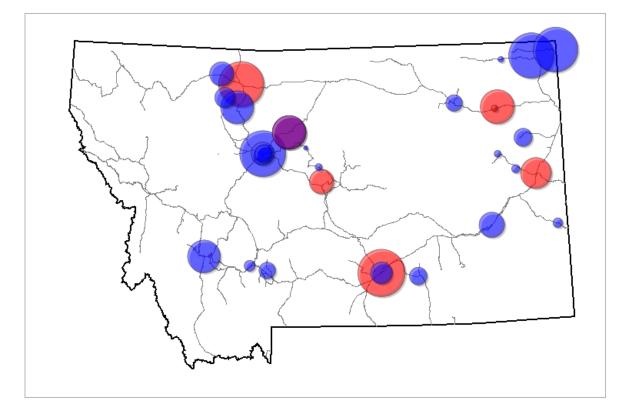
Figure 1: Elevator locations and rail lines in Kansas and Montana
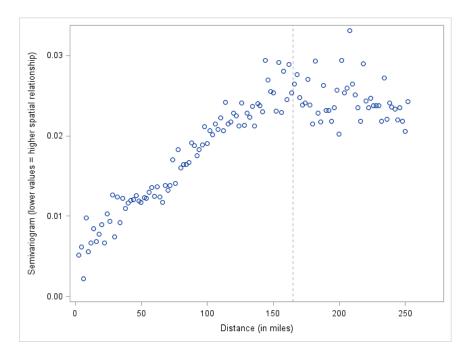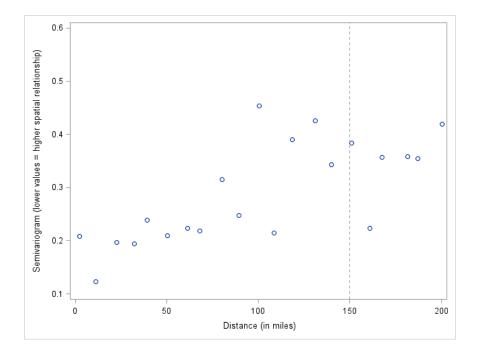
Figure 2: Empirical semi-variograms for Kansas and Montana

(a) Estimated nearby basis semi-variogram for Kansas elevators

(b) Estimated nearby basis semi-variogram for Montana elevators
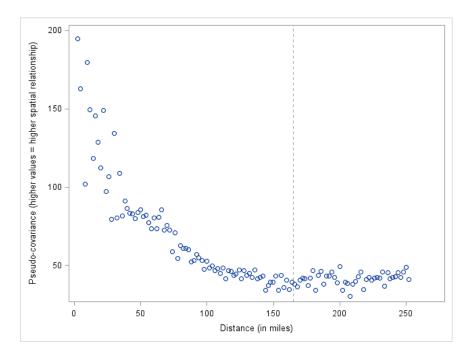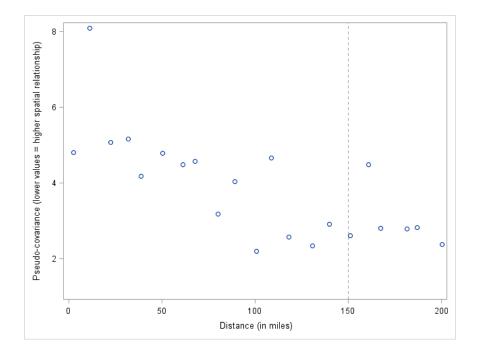
Figure 3: Empirical pseudo-covariance for Kansas and Montana

(a) Estimated nearby basis pseudo-covariance for Kansas elevators

(b) Estimated nearby basis pseudo-covariance for Montana elevators