Spatial Price Transmission and Market Linkages in US Framing Lumber Markets

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Abstract

We test the economic theory that price differences in spatially separated markets will be equalized through arbitrage activity using time series data on housing frame lumber prices in different regions of the United States. Wildfires, hurricanes, and other extreme weather events, as well as large swings in regional housing demand, can create shocks to geographically different lumber markets. The degree to which different lumber producing markets are interrelated is of interest to better understand how prices will respond to such shocks. Linked markets will realize adjustments that keep prices as equal as possible while allowing for differences directly related to the transfer costs necessary for arbitrage activity. Overly simplified tests will seem to support a lack of price transmission between markets or lag times between price adjustments that seem to contradict standard theory. This paper implements non-linear threshold models and non-parametric estimation techniques to demonstrate a more detailed price-linkage relationship that is better supported by economic theory.

Keywords: Local linear regression, price transmission, threshold autoregression.

JEL classification: Q11.

Introduction

Empirical testing of prices in spatially separated markets provides valuable information on levels of integration and affirmation of basic economic theory. Economic theory suggests that price differences in separate markets should be equalized through arbitrage activity, a process commonly referred to as the law of one price (LOP). Specifically, prices for homogeneous goods will adjust to as close to equal as possible while allowing for differences directly related to transfer costs of those goods between markets. This article will look at various tests of price transmission between US housing lumber markets. Overly simplified tests will often seem to support a lack of price transmission between markets, or lag times between price adjustments that seem to fly in the face of theory. The advent of non-linear threshold models and non-parametric estimation techniques provide a more detailed analysis that likely better matches both reality and theory. Both techniques will be used to estimate price transmission and convergence in US housing lumber markets.

Literature

A failure to account for unobserved transactions costs in empirical analysis has given rise to new methods of analysis of spatial price relationships. Transaction costs related to spatial arbitrage include transportation costs as well as product storage costs, loss from goods spoiled during shipment, etc. These costs can create non-linear price adjustments (Obstfeld and Taylor, 1997). Early work focused mainly on threshold effects and regime switching (Spiller, 1988). Threshold effects result when transaction costs create a range of differences in price that do not exceed transaction costs. In such a case, the marginal benefit of arbitrage activity does not exceed the marginal costs. Threshold models capture this non-linear behavior by estimating the adjustment of prices given differentials that exceed a no-trade range of price differentials. Balke and Fomby's (1997) seminal article on threshold cointegration establishes a model in which adjustment to a long-run equilibrium is discontinuous, following unit-root process within a small differential range and following a mean-reverting process outside.

Recently, nonparametric methods have been explored. For instance, Goodwin and Piggott (2001) uses various non linear and threshold models to analyze corn and soybean market integration. They find that when threshold behavior is included in the model, prices converge much fast for large price differences than standard models will predict. This implies that within some range of prices, prices may not converge. The lack of convergence makes sense in light of transaction costs that would limit the profitability of arbitrage opportunities, and matches theory surrounding LOP.

This article will use nonparametric methods to fit a model that does not require any assumptions about the functional form of the relationship between the prices in spatially separated markets. In looking at the convergence of real interest rates, Mancuso et al. (2003) notes the importance of bandwidth selection. Since nonparametric results are graphical, the bandwidth must be chosen carefully. Other articles have shown that nonparametric techniques reveal a higher level of price transmission than threshold models, which is seen in Serra (2006) and their analysis of EU pig markets. This article reinforces their findings.

Further research is being done with nonparametric techniques beyond the scope of this article.

Copula based models are being employed as in Goodwin et al. (2011) which looks at state dependence in price transmission.

Method

This analysis will focus on a reduced form estimation of price transmission followed by a non-parametric analysis between six different lumber markets. The standard autoregressive model for analysis is:

$$\Delta(p_t^i - p_t^j) = a + b(p_{t-1}^i - p_{t-1}^j) \tag{1}$$

where prices p are log prices in time t for two distinct regions i and j. The left-hand side includes a Δ because it is the difference in price differences between period t and $t-1$. We adopt this work from the literature, and some examples of work using the same basic form are Mancuso et al. (2003) and Serra et al. (2006). The coefficients a and b are predicted using OLS and interpreted as reflecting some level of market integration (Goodwin et al., 2011; Taylor, 2001). These articles show that b will tell the amount that the previous time period's price difference is corrected for in the next time period. Meanwhile, the constant a is some deviation from the equilibrium price differential. In this article, the constant could represent the transaction costs associated with arbitrage activity across the spatially separated lumber markets.

The resulting estimates allow for another convenient result relating to the speed of convergence. The half-life of a price deviation can be measured using the estimate for b which I will call β. Following Taylor (2001) and Goodwin et al. (2011) I note that the half life of a deviation is given by $ln(0.5)/ln(\beta)$ which will give the number of weeks required to eliminate half of the deviation from the equilibrium price difference. The time-series properties of the adjustments are examined using Augmented Dickey-Fuller tests, and the results are given in Table 2. Rejecting the null hypothesis of nonstationarity implies that market prices move together and these markets exhibit cointegration.

Next, I estimate the adjustment process using non-linear threshold models. The threshold model estimated is given by

$$\Delta Y_t = \theta_1' x_{t-1} 1_{(Z_{t-1} < \lambda)} + \theta_2' x_{t-1} 1_{(Z_{t-1} \geq \lambda)} + e_t \tag{2}$$

where $Y_t = (p_t^i - p_t^j), i \neq j$, and $x_{t-1} = (p_{t-1}^i - p_{t-1}^j), i \neq j$, the price differentials between markets last time period as specified above. $1(\cdot)$ is the indicator function, and λ is the threshold value for price differentials. Z_{t-1} is equal to Y_{t-m} where $m \geq 1$ is a delay parameter. This formulation forces the indicator function to equal 1 if the price differential in a specified previous period, most commonly the previous period, is above the threshold for trade or no-trade conditions. We estimate λ in an initial stage before estimating (2) using OLS. Equation (2) is a two-regime model, while specifying a third θ and λ inequality would allow for a three-regime model. It is sometimes the case that one region in a region-pair always has the higher price, making a three-regime model unnecessary.

The threshold value λ is determined using a grid search. First we test whether a one or two threshold model is more appropriate. The grid search is conducted over values from the range of values in the dataset, and limited such that each regime will include at least 15% of the total number of observations. The 15% condition is not binding for any estimated model for lumber region pairs. The grid search selects λ to minimize BIC. In the case of a three-regime model, the neutral band may be asymmetric around a price differential of zero. Serra (2006) finds asymmetries in early 20th century egg markets. The grid search used allows for asymmetric threshold values. Next, a model is estimated using the threshold values from the grid search.

I compare these results to a non-parametric fitting of the price difference data. It is reasonable to expect that price adjustments are not linear in nature, and will be larger given a larger difference in prices between regions as arbitrage opportunities exceed transaction costs and become more lucrative. This is sometimes understood within a regime switching context, where no trade occurs within a band of price differences that are less than the transfer costs, and trade begins to occur once that price difference exceeds the transfer costs. Imposing and estimating thresholds still requires some structure in the estimation, but non-parametric techniques do not need to assume a specific functional form, as in (Serra et al., 2006). Local linear regression techniques have been used and can allow for non-constant neutral price bands, which seems more reasonable than a constant neutral band over time as in some threshold models. This article used the LOESS procedure in SAS and compared results using both generalized cross validation (GCV) and the AICC1 selection criteria.

Confidence bands are then estimated at the $\alpha = 0.05$ level.

Nonparametric estimation also does not assume that there is no form to the adjustment of prices. If markets adjust perfectly with each other, then a nonparametric regression line of price adjustments will result in a 45-degree line. Because there are no parameters on which to base tests, the results of such estimation must be shown graphically.

Data

The data is weekly price data on 2x4 framing lumber from 1994 to 2010 from Random Lengths. This article looks at the prices of kiln-dried pine and fir 2x4 framing lumber from six distinct regions in the United States. The Spokane region is inland Hem-Fir or White Fir from mills near Spokane, WA. Douglas Fir prices come from coastal Oregon mills, while Hem-Fir come from coastal Washington mills. The West region includes mills in Texas, Arkansas, Oklahoma, and Louisiana west of the Mississippi River. The Central region is price data from mills in Mississippi, Alabama, and Louisiana east of the Mississippi River. Finally, the East region is pricing data from mills in Georgia, Florida, and South Carolina. The prices are in dollars per thousand board feet. A graph of price movements over time is shown in figure 1.

The housing market generally has experienced significant impacts in recent years, and this will directly affect demand and prices for housing lumber. Significant changes in home construction require accurate price information from the input market, so a better understanding of how prices are transmitted across regions could be very useful. Severe weather impacts like Hurricane Katrina and the subsequent flooding could affect some of the regions represented here in terms of the need for new home construction. Flooding along the Mississippi River also took place in 1993, so it's possible that lagged construction following that disaster may be represented in the earliest portion of this data. The recession of 2008 and subsequent housing bubble is also included in this time period.

Empirical Estimation

The first step is to estimate parameters for the basic linear equation shown in (1) for each pair of regions in the dataset. The results of these OLS regressions are shown in table 1. The estimates for b are all significant and tell us that it could be reasonable to believe that a price difference in the previous period will lead to a smaller difference of price differences in the next period. Half-lives for the West and East and East and Central regional differences are quite long: both require over 18 weeks to reduce half the price difference, leading us to believe that these markets are not that closely integrated. Half-life for the difference between West and Central regions is 6.7 weeks, which implies a quicker reduction in the price differences and more market integration. However, these estimates could be misleading since no threshold effects are included. The graphs of these predicted lines are shown in figures 2-3.

Non-linear results using self-exciting threshold autoregression methods are reported in tables 2-4. We report p-values from the test of a linear model against a one or two threshold model as well as p-values for a test of a one threshold model over a two threshold model. The estimates show that regions nearer each other exhibit more cointegration behavior than very distant region-pairs. For instance, the Hem-Fir and Douglas Fir regions in the Pacific northwest both strongly reject the null of a linear model in favor of a threshold model. The Spokane and East region pairing fails to reject the null of a linear model, though there is likely little arbitrage between these regions due to long transportation distances between them. The failure to reject means that no threshold value was found searching over all price differentials seen in the data that would cause non-linear adjustment process between these two regions. Threshold values range from $1 to $72 per thousand board feet. The variation in threshold values can be interpreted as differences in transaction costs between different region pairs.

The nonparametric estimation reveals linkages in some cases, and demonstrates smoother transitions from large price differentials. Locally weighted lines are estimated with confidence intervals using the AICC1 smoothing parameter selection criteria. This option appeared to give slightly tighter confidence bands than the GCV selection criteria (figures 5-7). The weighted estimates for each point on the line are shown with a 95% confidence interval surrounding, and each graph has been scaled to be the same for better comparison. The West and Central region shows a heavy degree of adjustment just outside of a region of small actual price differences, and the graph shows that larger price differences adjust at a greater rate than small ones. A perfectly integrated market would show price adjustments on a -45-degree line.

The other two region pairs show a much smoother predicted adjustment of prices which are close to linear. Even with large actual price differences, the adjustment of the difference between this period and last period is small. The Central and East region shows a much tighter range of price differentials. The log price differences slower adjustment in these cases reinforce the finding of a less integrated market. This could be due to high transaction costs or because the markets rarely see large price differences.

Conclusion and Discussion

The markets for housing lumber in terms of mill prices across regions are shown to have varying levels of integration. The markets do not appear to be perfectly integrated, with both the basic OLS estimation of price adjustments and the nonparametric fittings of the data showing a level of price correction outside of what would be expected in the perfect case. Half-life adjustments are predicted using the OLS estimates. Nonparametric estimation techniques are used to graphically show the non-linear nature of the price adjustments. While the adjustments between two of the regions shows dramatic adjustment behavior, two other region pairs show a much smoother adjustment. Further work could control for the extreme ends of the price differentials in nonparametric estimation.

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Table 1: OLS Estimates of Autoregressive Error-Correction Price Parity Model

Parameter	Estimate	Standard Error	t-Ratio	Deviation Half-Life	R^2
West and Central					
a	0.000014	0.000343	0.04		0.0489
b	0.09772*	0.01512	-6.46	6.74068443	
West and East					
a	-0.000693	0.000441	-1.57		0.0185
b	0.03705*	0.00947	-3.91	18.35967164	
East and Central					
a	-0.000683	0.00033	-2.07		0.018
b	0.03608*	0.00934	-3.86	18.86270023	

An asterisk indicates statistical significance at the $\alpha = 0.10$ or smaller level. The deviation half-lives represent the weeks required to eliminate one-half of the deviation from equilibrium, and they are calculated using $ln(0.5)/ln(1-\beta)$. Note that β is positive because the formula subtracts if from the constant.

Table 2: Threshold Autoregression Estimates

	Hem-Spo		Hem-Dou			Hem-Wst		Hem-Cnt	
Coefficient	In Threshold	Out Threshold	Low	Mid	High	In	Out	In	Out
β_1	0.010 (0.013)	-0.011* (0.005)	-0.011* (0.005)	-0.013 (0.016)	0.091*** (0.027)	-0.002 (0.008)	-0.017** (0.006)	0.029 (0.021)	-0.016*** (0.005)
β_2	-0.018 (0.059)	0.282*** (0.044)	0.282*** (0.043)	-0.220* (0.086)	-0.002 0.090)	-0.419*** (0.042)	0.603*** (0.065)	0.391*** (0.060)	0.516*** (0.044)
β_3	0.026 (0.059)	0.035 (0.043)	0.035 (0.043)	0.151 (0.092)	-0.000 (0.081)	-0.057 (0.042)	-0.163** (0.062)	-0.081 (0.059)	-0.124** (0.043)
Threshold		<-40	<-40		>-28		<-73		<-39
Setar Threshold Test Pvals	1vs2: 0.555 1vs3: 0.660		1vs2: 0.000 1vs3: 0.000 2vs3: 0.01			1vs2: 0.635 1vs3: 0.840		1vs2: 0.745 1vs3: 0.435	

An asterisk indicates statistical significance at the α = 0.10 or smaller level, (**) is significance at α = 0.05, and (***) is significance at α = 0.01.

Table 3: Threshold Autoregression Estimates

	Hem-Est		Spo-Dou			Spo-Wst	
Coefficient	In	Out	Low	Mid	High	In	Out
β_1	0.029 (0.021)	-0.016*** (0.005)	-0.030** (0.011)	-0.075 (0.038)	-0.106*** (0.020)	-0.042*** (0.012)	-0.031*** (0.007)
β_2	0.391*** (0.060)	0.516*** (0.044)	0.352*** (0.067)	0.464*** (0.103)	0.165*** (0.044)	0.613*** (0.056)	0.583*** (0.043)
β_3	-0.081 (0.059)	-0.124** (0.043)	-0.014 (0.078)	0.046 (0.086)	0.046 (0.044)	-0.074 (0.057)	-0.031 (0.044)
Threshold		<-39	<-27		>-9		<1
SetarTest Pvals	1vs2: 0.62 1vs3: 0.63		1vs2: 0.005 1vs3: 0.005 2vs3: 0.08			1vs2: 1.00 1vs3: 0.99	

An asterisk indicates statistical significance at the α = 0.10 or smaller level, (**) is significance at α = 0.05, and (***) is significance at α = 0.01.

Table 4: Threshold Autoregression Estimates

	Spo-Est			Wst-Est		Cnt-Est	
Coefficient	Low	Mid	High	In	Out	In	Out
β_1	-0.028*** (0.007)	-0.016 (0.025)	-0.043** (0.015)	-0.024 (0.013)	-0.051*** (0.011)	-0.014 (0.014)	-0.041*** (0.010)
β_2	0.643*** (0.058)	0.503*** (0.062)	0.7234*** (0.060)	0.350*** (0.041)	0.594*** (0.068)	0.257*** (0.043)	0.195** (0.063)
β_3	-0.066 (0.058)	-0.122 (0.065)	-0.119* (0.059)	0.057 (0.040)	-0.065 (0.070)	0.010 (0.042)	-0.069 (0.063)
Threshold	<-33		>-5		<-18		<-15
Setar Threshold Test Pvals	1vs2: 0.225 1vs3: 0.065 2vs3: 0.035			1vs2: 0.04 1vs3: 0.02 2vs3: 0.205		1vs2: 0.740 1vs3: 0.845	

An asterisk indicates statistical significance at the α = 0.10 or smaller level, (**) is significance at α = 0.05, and (***) is significance at α = 0.01.

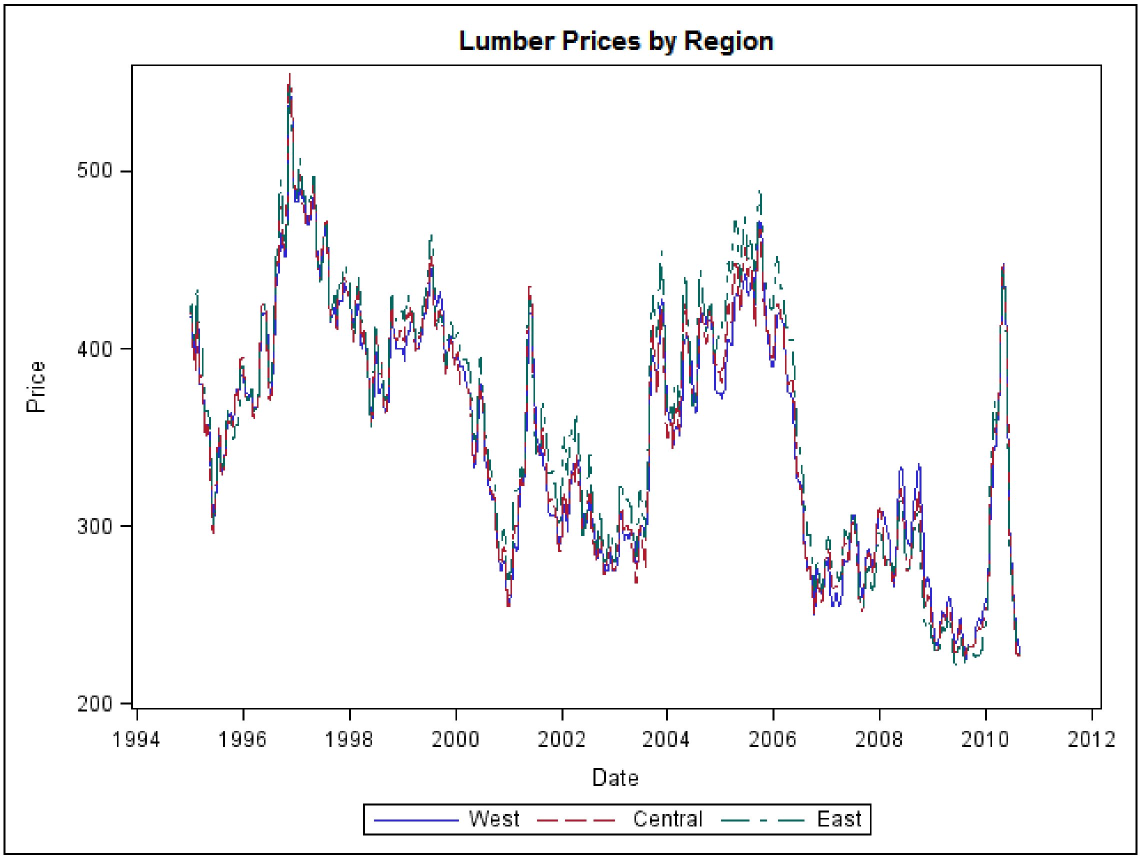
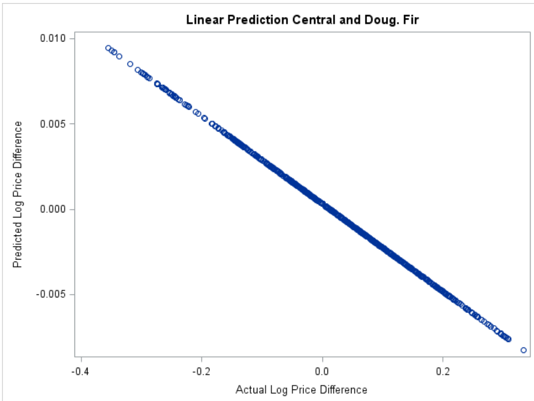
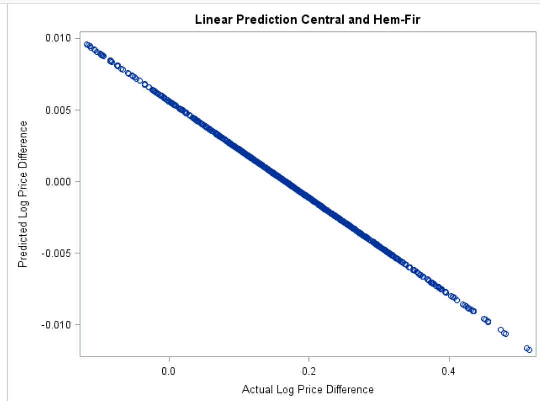


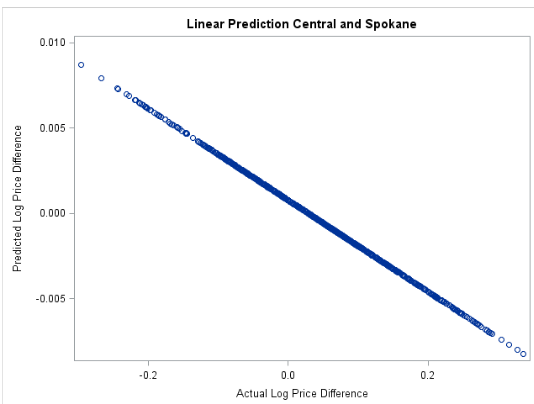
Figure 1: Price Movements in West, Central and East Regions



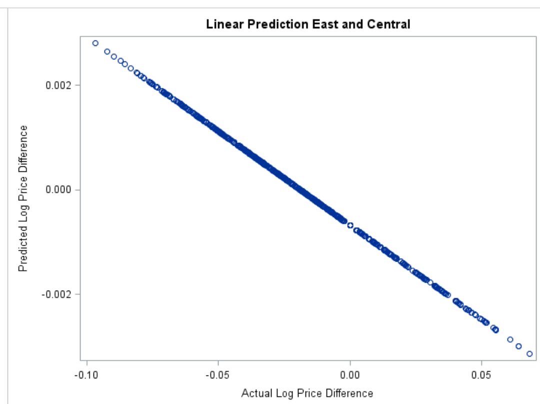
(a) Central - Douglas Fir



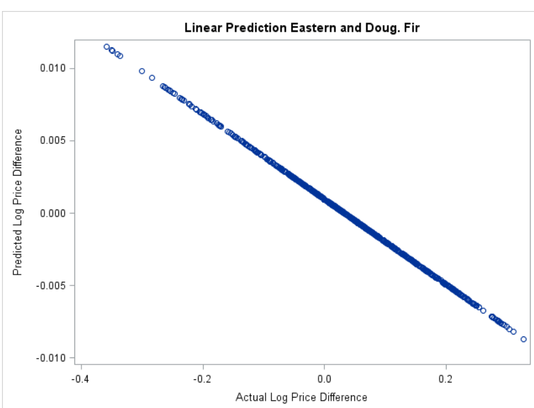
(b) Central - Hem Fir



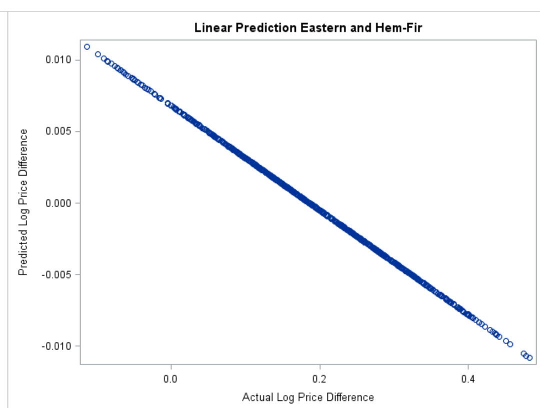
(c) Central - Spokane



(d) East - Central

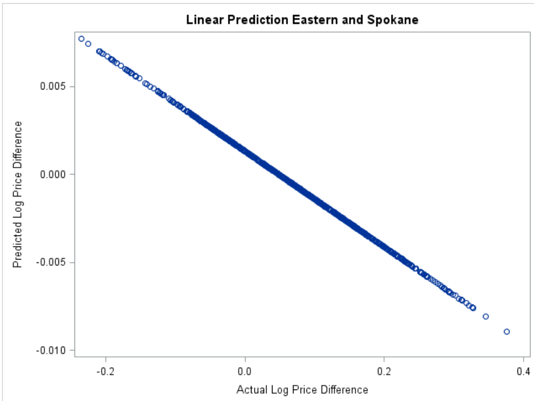


(e) East - Doug. Fir



(f) East - Hem Fir

Figure 2: Linear Prediction vs. Actual Price Differences



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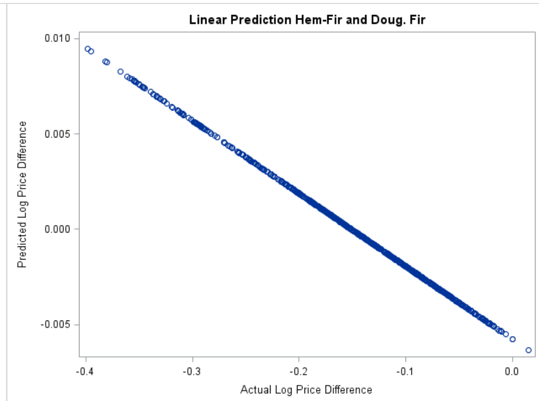
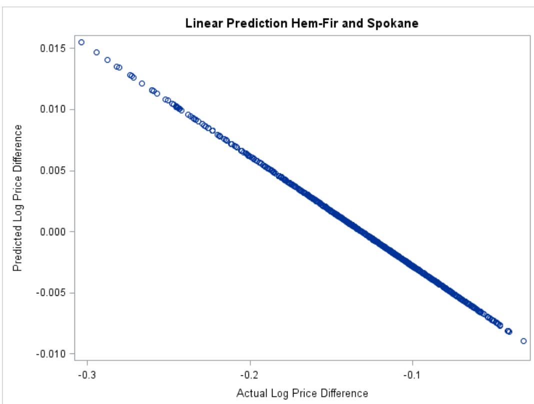
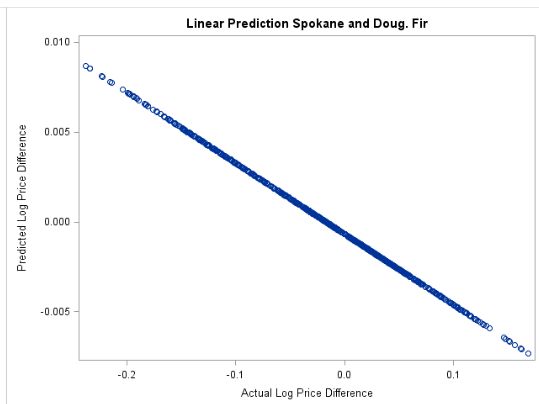


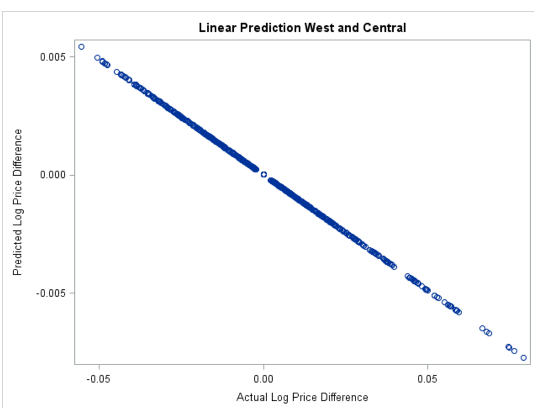
(b) Hem Fir - Doug. Fir



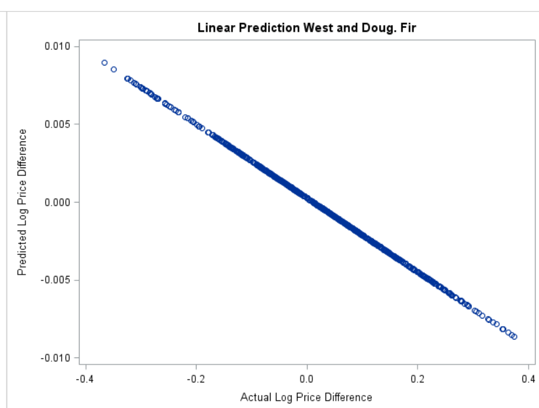
(c) Hem Fir - Spokane



(d) Spokane - Doug. Fir

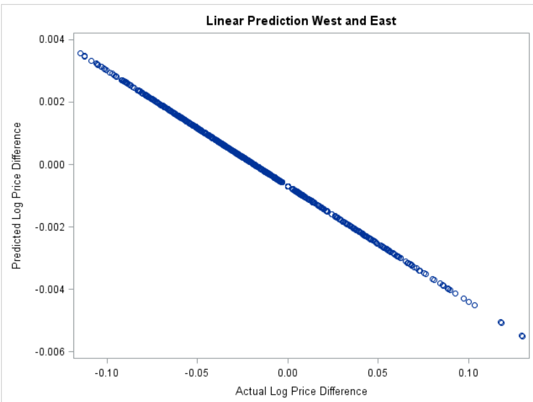


(e) West - Central

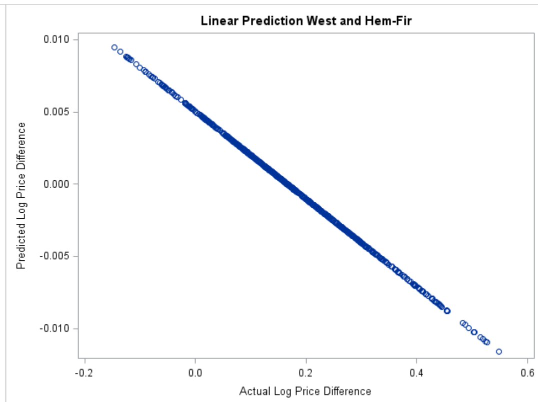


(f) West - Doug. Fir

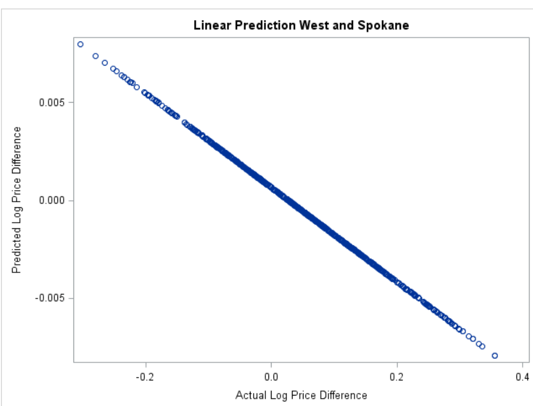
Figure 3: Linear Prediction vs. Actual Price Differences



(a) West - East

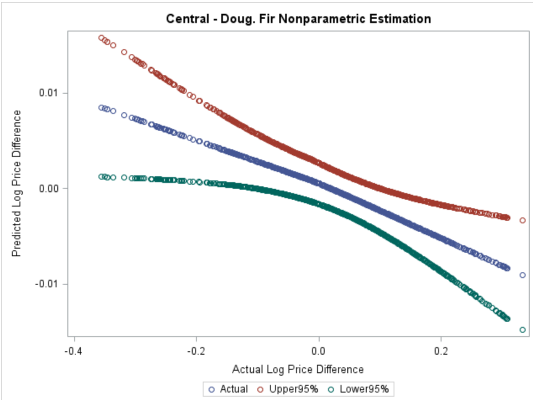


(b) West - Hem Fir

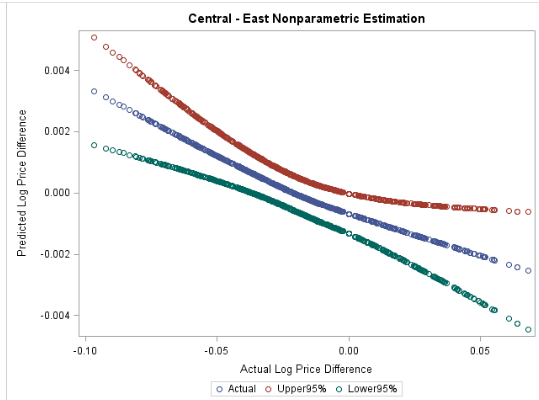


(c) West - Spokane

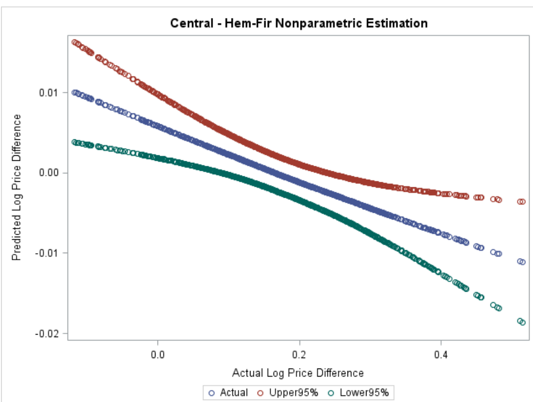
Figure 4: Linear Prediction vs. Actual Price Differences



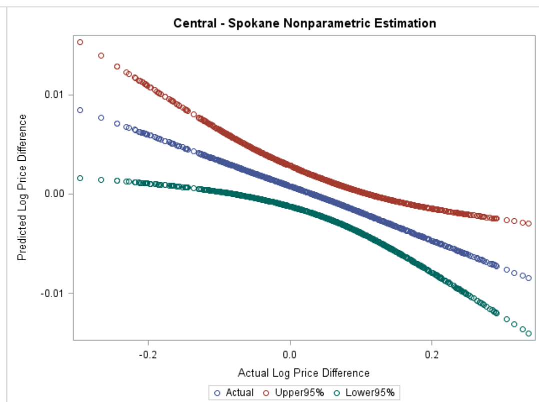
(a) Central - Douglas Fir



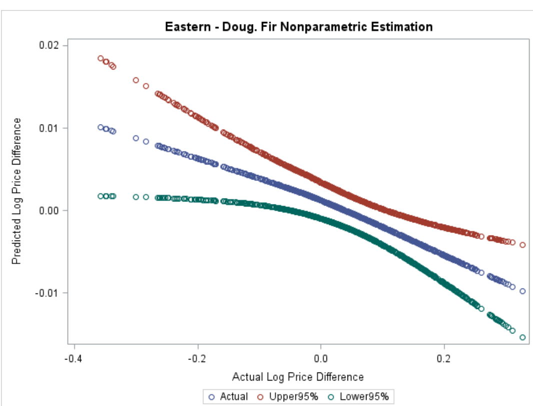
(b) Central - East



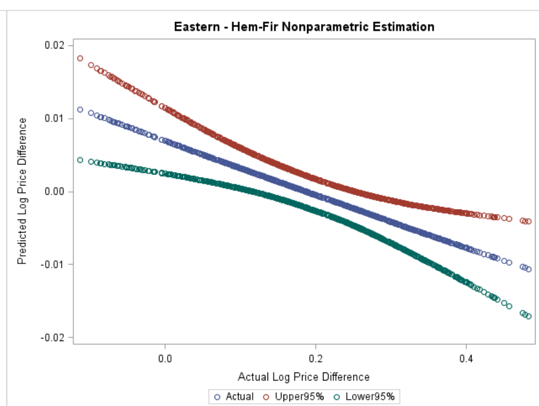
(c) Central - Hem Fir



(d) Central - Spokane

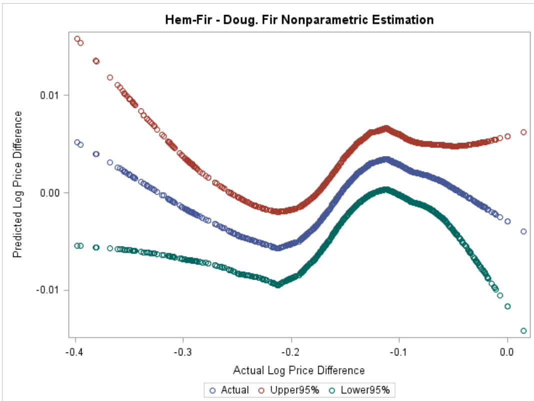


(e) East - Doug. Fir

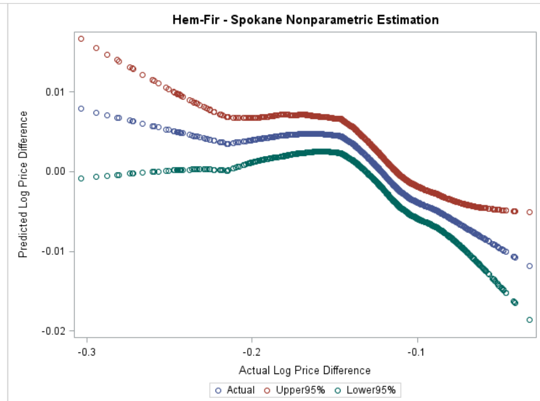


(f) East - Hem Fir

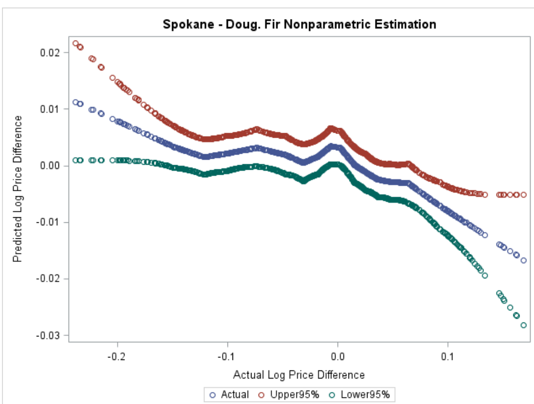
Figure 5: Non-paramteric Estimation of Price Transmission



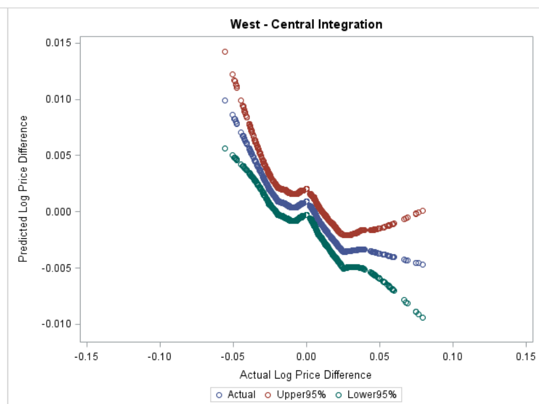
(a) Hem Fir - Doug. Fir



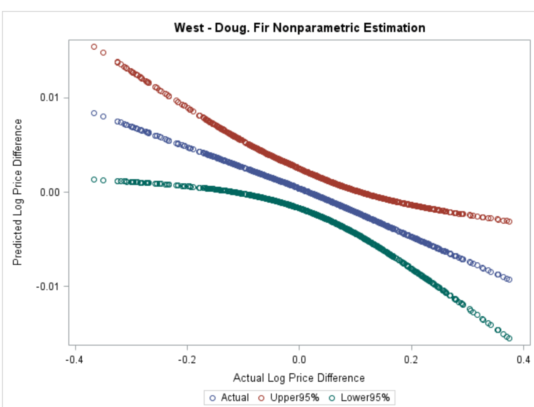
(b) Hem Fir - Spokane



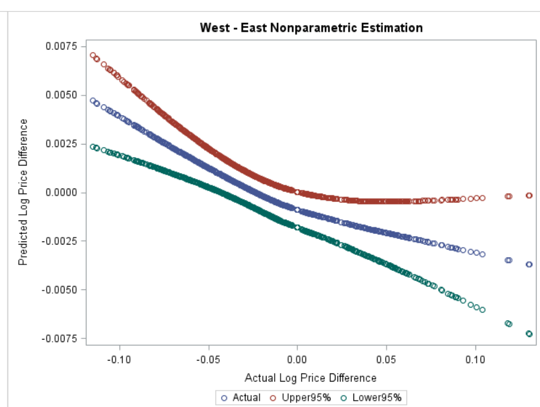
(c) Spokane - Doug. Fir



(d) West - Central

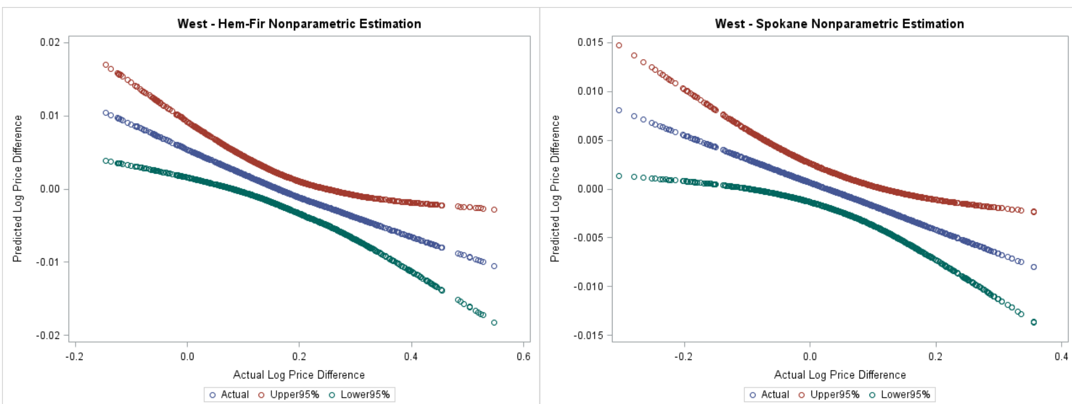


(e) West - Doug. Fir



(f) West - East

Figure 6: Non-paramteric Estimation of Price Transmission



(a) West - Hem Fir

(b) West - Spokane

Figure 7: Non-paramteric Estimation of Price Transmission