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economics

Price Linkages between Spot and Futures Markets for Softwood Lumber

Rajan Parajuli and Daowei Zhang

Price discovery is one of the central functions of futures markets. In this article, we evaluate the relative contributions of spot and futures markets to the price discovery of softwood lumber. We estimate a bivariate vector error correction model using weekly lumber futures and spot price data from 1980 to 2015 and assess the price linkages and dynamic relationship between lumber futures and spot markets. Our empirical results show that the futures market plays a dominant role in price discovery of softwood lumber. In certain periods of the United States-Canada softwood lumber dispute, the lumber spot market also plays a significant role in the price discovery of softwood lumber in the United States.

Keywords: softwood lumber, vector error correction model, common factor weights, cost of carry model, autoregressive distributed lag (ARDL) bounds test

Futures trading is a well-established derivative market with the primary social benefits of hedging price risks, facilitating price discovery, offering spreading strategies over other sectors, and allocating resources more efficiently (Fortenbery and Zapata 1997, Chicago Mercantile Exchange Group 2016). Price discovery refers to the relative contribution of a market in processing new information to determine equilibrium prices. It is primarily a mechanism for determining the equilibrium price through the interactions of market participants, which takes the supply and demand expectations into account (Schreiber and Schwartz 1986). Theoretical arguments posit that price discovery takes place primarily in the futures market because futures prices reflect the new information faster than spot prices due to lower transaction costs, ease of short selling, and active involvement of a large number of buyers and sellers (Silvapulle and Moosa 1999).

The purpose of this study is to evaluate the contribution of spot and futures markets to the price discovery of softwood lumber in the United States. The available empirical evidence on the function of price discovery in various futures markets is mixed. Whereas Garbade and Silber (1983), Brockman and Tse (1995), Kavussanos and Nomikos (2003), Caporale et al. (2014), and Adammer et al. (2015) reported a dominant role of futures markets in the price discovery of agricultural and storable commodities, Quan (1992), Fortenbery and Zapata (1997), and Manfredo and Sanders (2008) concluded that the spot and futures price series are not cointegrated, indicating a limited or no role of futures prices in the price discovery process.

Even though Random Lengths lumber futures contracts have been traded in the Chicago Mercantile Exchange since the early 1970s, empirical literature on the lumber futures market is limited. The lumber futures market is a relatively thin exchange market with a daily trading volume of around 1,040 in the nearest futures contract in the last 5 years (Commodity Research Bureau [CRB] 2015). Early studies by Oliveira et al. (1977), Buongiorno et al. (1984), and Holtkamp (1984) examined the forecasting performances of lumber futures price series. Similarly, Deneckere et al. (1986) investigated the risk hedging properties of the lumber futures market and concluded that 50–90% of price volatility could be addressed with an optimum use of the lumber futures market. Rucker et al. (2005) used daily lumber futures price series in an event study to assess the lumber market reactions to new market and policy announcements, and Zhang and Sun (2001) looked into lumber price volatility associated with United States-Canada softwood lumber trade dispute. Karali and Thurman (2009) and Karali (2011) examined the volatility in lumber futures caused by announcements in housing starts and the softwood lumber trade dispute, respectively. To evaluate the relationship between the spot and futures prices for softwood lumber, Manfredo and Sanders (2008) studied price discovery in the lumber futures market along with a private lumber forward market and reported that between September 2002 and February 2005, lumber spot and futures/forward price series were not cointegrated. Their findings based on Granger causality tests, however, revealed unidirectional causality running from the lumber futures to the spot market in the short run. Similarly, other studies that investigated the

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Affiliations: *Rajan Parajuli (rparajuli@tfs.tamu.edu), Auburn University, School of Forestry and Wildlife Sciences, Auburn, AL, Texas A&M Forest Service, College Station TX 77845. Daowei Zhang (zhangd1@auburn.edu), Auburn University.*

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price linkages between the lumber spot and futures markets are Deckard (2000), He and Holt (2004), and Hasan and Hoffman-MacDonald (2012). These studies, however, examined the price relationship based on a small data sample, using just a few years of futures and spot prices. Interestingly, Deckard (2000) and Hasan and Hoffman-MacDonald (2012) used monthly and bimonthly spot and futures prices to investigate their relationship.

Based on the theoretical foundation of the cost of carry model (Kaldor 1939, Fama and French 1987), we examine the characteristics of price movements in spot and futures markets and investigate whether one market is dominant in terms of reflecting new information and price discovery. Unlike previous studies that used only 3-year data, we employ continuous weekly data series of spot and futures prices from January 1980 to October 2015 with total observations of 1,838. We also evaluate the spot and futures prices movements in the various episodes of the lumber trade dispute between the United States and Canada. Our results show that the lumber futures and spot prices have a long-run cointegrating relation, and the futures and spot markets contribute to the price discovery of softwood lumber in the United States, but the futures market plays a leading role.

The next section presents the cost of a carry model as a foundation of the bivariate vector error correction (VEC) relationship between spot and futures prices and describes the econometric estimation methods used to estimate the VEC model. The subsequent section explains the data used to estimate our empirical model, followed by empirical results. The last section concludes with discussion.

Econometric Methods

The long-run relationship between spot and futures prices of a commodity can be explained by the cost of carry or theory of storage model. The cost of carry model postulates that the difference between contemporaneous futures and spot prices of a commodity should equal the cost of carrying the commodity until the maturity of the futures contracts. The cost of carrying term usually consists of the interest rate as a cost of capital invested, the storage and warehousing cost, and the convenience yield (Fama and French 1987). Based on the theory of storage model, the long-run spot-futures price relationship of softwood lumber can be formulated in an econometric representation as (Adammer et al. 2015)

$$lf_t(T) = \beta_0 + \beta_1 ls_t + ec_t \tag{1}$$

where $lf_t(T)$ represents the log-transformed futures price of softwood lumber at time t for delivery (contract expiration) at time T and ls_t denotes the log-transformed spot lumber price at time t. The ec_t term in Equation 1 represents the cost of carrying the futures contract, which can be expressed as the estimated error correction term in a long-run cointegrating relationship normally and independently distributed as $\sim NID(\bar{e}c, \sigma^2_{ec})$ (Low et al. 2002, Adammer et al. 2015).

Using the Granger representation theorem, a system of variables containing spot and futures prices of lumber in Equation 1 can be represented in a VEC framework as

$$\Delta X_t = \pi ec_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta X_{t-i} + \varepsilon_t;$$

$$\varepsilon_t = \begin{pmatrix} \varepsilon_{s,t} \\ \varepsilon_{f,t} \end{pmatrix} \sim N(0, \Sigma) \tag{2}$$

where Δ is the first difference operator, $X_t = [ls_t, lf_t(T)]'$, and Γ matrices represent the short-run adjustment coefficients. Further, the long-run impact matrix $\pi = \alpha\beta'$, where β represents the vector of cointegrating parameters, and $\alpha = [\alpha_s, \alpha_f]'$ is the vector of error correction coefficients corresponding to spot and futures prices, respectively. The estimates of α_s and α_f are expected to have opposite signs so that the short-term disequilibrium in one price would be corrected through the appropriate movement in another price (Caporale et al. 2014, Shrestha 2014).

The error correction coefficients obtained from the estimation of Equation 2 serve an important role in measuring the contribution of spot and futures prices to the price discovery of softwood lumber in the United States. They not only demonstrate the direction of causality between spot and futures prices but also measure the speed of adjustments to the long-run equilibrium state of spot and futures price of softwood lumber. To maintain the long-run steady relationship between spot and futures prices, the error correction adjustments in the short run must occur in either the spot price or the futures price or in both (Harris et al. 1995). For example, if α_s is statistically significant and α_f is insignificant in Equation 2, departures from the equilibrium condition are corrected mainly in the spot market. And if α_s is statistically insignificant and α_f is significant, the futures price moves to correct the disequilibrium in the short run. Finally, if both α_s and α_f are statistically insignificant, the spot and futures prices do not converge to the long-run equilibrium state.

The error correction coefficients can also be used to quantify the relative contribution of the spot and futures prices to price discovery. The common factor weights method, devised by Schwarz and Szakmary (1994) and Gonzalo and Granger (1995), is used to calculate the relative magnitude of adjustment coefficients in the price discovery process. Several recent studies (e.g., Caporale et al. 2014, Shrestha 2014) have used this approach of measuring price discovery between the spot and futures prices in commodity markets. The common factor weights of the futures (θ_f) and spot (θ_s) markets of softwood lumber are calculated using the concept of permanent-transitory decomposition-based information share measures:

$$\theta_f = \frac{\alpha_s}{\alpha_s - \alpha_f}, \quad \theta_s = 1 - \theta_f = \frac{\alpha_f}{\alpha_f - \alpha_s} \tag{3}$$

The magnitudes of both θ_f and θ_s depend on the adjustment coefficients in spot and futures prices, and the sum of the two common factor weights is restricted to 1. If the estimated value of θ_f is greater than 0.5, the futures market dominates in price discovery (Adammer et al. 2015). In other words, more price discovery occurs in the futures market, as the adjustment reaction is relatively faster in the futures market.

The softwood lumber trade dispute between the United States and Canada, termed the softwood lumber war (Zhang 2007), has been a persistent trade battle for more than three decades. This trade issue has created substantial distortions in the US domestic lumber market, as Canada is the largest exporter of softwood lumber to the United States, capturing roughly one-third share of the US lumber market, and as the US lumber trade with other countries is small. Over the last three decades, the two countries implemented several short-term agreements including the 5-year Memorandum of Understanding (MOU) for the period of 1987–1991, the Softwood Lumber Agreement (SLA) 1996 for the period of 1996–2001, and the SLA 2006 for the period of 2006–2015 (Zhang 2007, Parajuli et al. 2015). The period between the expiration of SLA 1996 and the

Table 1. Descriptive statistics (before being log-transformed): January 1980–October 2015.

Variable	No. of observations	Mean	Minimum	Maximum	SD	Correlation with spot
Spot price (s_t)	1,838	251.96	124.00	480.00	79.32	1
Futures price $f_t(1)$	1,838	253.61	119.00	488.50	77.47	0.98
Futures price $f_t(2)$	1,838	257.72	125.00	463.90	73.60	0.96

implementation of SLA 2006 was tumultuous as the United States imposed several countervailing duties (CVD) and antidumping (AD) tariffs ranging from 2 to 32%. To evaluate the spot-futures price relationship in these distinct phases of the trade dispute, we split the whole data into several subsamples in line with the trade dispute episodes and examine the price discovery process in the US softwood lumber futures and spot markets.

Data

As noted, our data set includes weekly averages of lumber futures and spot prices starting from January 1980 to October 2015. The daily settlement price of each individual Random Lengths lumber futures contract and the weekly spot price of 2×4 #2 and better, kiln-dried Western spruce-pine-fir lumber type are obtained from CRB (2015). This weekly spot price series of corresponding lumber type traded in the lumber futures market is originally released by Random Lengths every Friday at 2:00 PM (Pacific Time) (Random Lengths 2015). Random Lengths is a leading source of information for the wood products industry, which reports weekly price series of various lumber types in the United States and Canada based on its actual survey of market participants. The reported spot price of #2 and better, Western spruce-pine-fir lumber type is the benchmark price on free on board mill basis. Furthermore, the daily settlement prices on every Friday are used to construct the weekly price series of lumber futures. The corresponding Thursday settlement prices are considered, in case price information is not reported on Friday due to holidays.

The Random Lengths lumber futures contracts are traded in working business days at CME between 9:00 AM and 1:05 PM Central Time. The lumber contracts, with a unit volume of 110,000 board feet, expire every alternate month. The contracts mature on the 15th of the month, and the delivery months are January, March, May, July, September, and November. The delivery unit of each lumber contract consists of 2×4s of random lengths from 8 to 20 ft, and the primary deliverable lumber species is Western spruce-pine-fir including Hem-Fir, Engelmann spruce, and lodgepole pine (Karali 2011, CME 2015).

Because five to seven contemporaneous contracts are traded daily in the futures exchange with different delivery dates, several approaches of rolling over the contracts have been used in empirical studies to compile a single representative continuous price series for the futures market (Ma et al. 1992, Karapanagiotidis 2014). Most of the recent studies in commodity futures markets just appended the two futures price series without any price adjustment from the nearby maturing contract to the next-out contract. These authors selected the contract expiration date (Manfredo and Sanders 2008) to the 2 months before the contract expiration (Rucker et al. 2005) as a rollover point of two subsequent lumber futures contracts.

For this study, we use the last trading day of the expiring contract [$f_t(1)$] as a rollover date to construct a continuous price series of lumber futures,[1] which is basically the first nearby futures price series. To examine the robustness of the futures contract series, we also construct another futures price series by selecting 2 months [$f_t(2)$] before the contract expiration as rollover dates, that is, the second nearby contract series. For example, in $f_t(1)$, the futures price used for the period of Nov. 17, 2014–Jan. 15, 2015 is the Friday settlement price of the January 2015 contract. And in $f_t(2)$, for the same period we use the settlement price of the March 2015 contract. The daily market activities, in particular volume traded and open interest per day, also support the construction of two continuous futures price series from the first and second nearby contracts. The lumber futures contracts are usually active starting from 4 months before the expiration date.

Empirical Results

Table 1 presents the descriptive statistics of the nominal data used for the analysis. The spot price of softwood lumber has the lowest mean of $252/thousand board feet (mbf) with the highest SD of 79.32. The average price differential between the spot and nearby futures price series is around $1.5/mbf over the sample period. From the first nearby futures contract to the second nearby contract, the mean value of the futures price series increases with a decreasing trend in price volatility. Similarly, the spot price series has a higher correlation value with the first nearby futures price series than with the second nearby futures price series. Caporale et al. (2014) reported similar trends for spot and futures series of crude oil prices. The spot and futures prices track each other closely (Figure 1). Figure 1 depicts the several lumber trade dispute episodes. Both spot and futures price series fluctuated less in the earlier weeks before 1990 than afterward.

The empirical estimation of the bivariate VEC model starts with testing for the unit root and stochastic properties of each series, followed by the cointegration test and estimation of an error correction model. Among the several unit root tests available, the Dicky-Fuller generalized least squares (DF-GLS) test (Elliott et al. 1996) is used in each series, as it is considered to be a more powerful test. The DF-GLS test rejects the null hypothesis of unit root at the level of log-transformed data (Table 2). The unit root test in the $lf_t(1)$ series is only rejected at the 10% level of significance. The test suggests that all of the lumber spot and futures price series are found to be stationary, indicating an integration order of $I(0)$. We also use the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root test (Kwiatkowski et al. 1992), which differs from the other unit root tests by having a null hypothesis of stationarity of the time-series data. In contrast, the KPSS test concludes that all of the price series have unit root at the level and are stationary at the first difference, indicating $I(1)$ order of the variables (Table 2). Because two different unit root tests produce opposite results, we also use the Zivot-Andrews unit root test (Zivot and Andrews 1992) to evaluate whether a structural break affects the unit root properties of the data. The Zivot-Andrews test allows an endogenous structural break in both the trend and intercept while estimating a test statistic in the unit root test. Parajuli and Chang (2015) also used the Zivot-Andrews unit root test in the softwood sawtimber stumpage

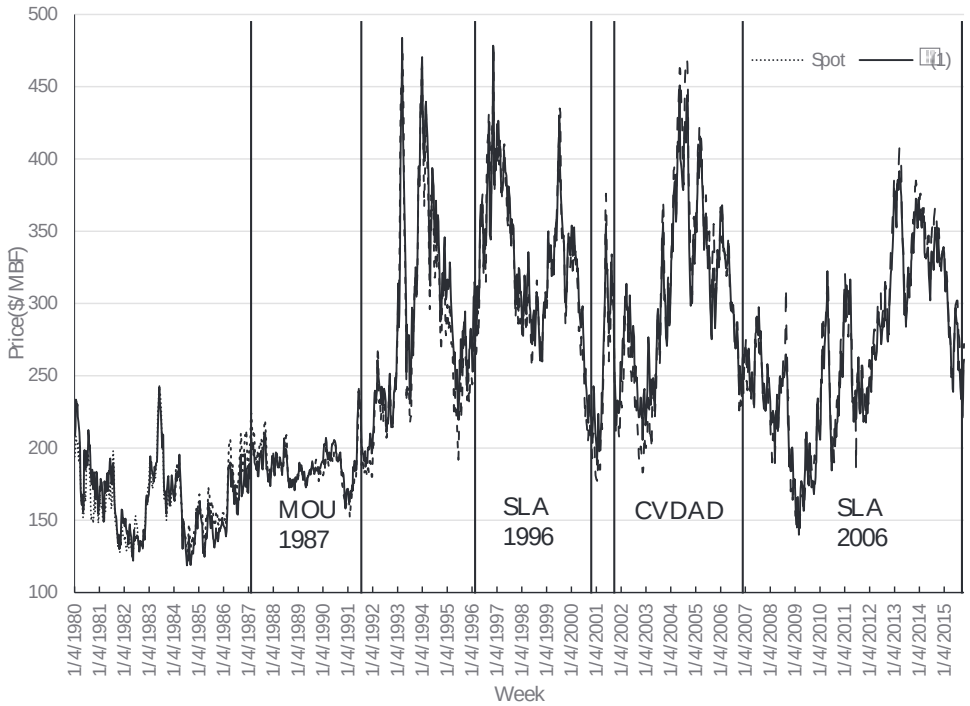

Figure 1. Weekly spot and futures price series of softwood lumber.

Table 2. Unit root and stationarity tests.

Variable	DF-GLS test		KPSS test		Zivot-Andrews test	
	Level	First diff	Level	First diff	Level	First diff
Full sample period: January 1980–October 2015 (1,838 obs)						
ls_t	−3.19[a]		2.98[a]	0.02	−5.95[a]	
$lf_t(1)$	−2.81[b]	−30.17[a]	2.86[a]	0.04	−5.67[a]	
$lf_t(2)$	−3.13[a]		3.08[a]	0.04	−5.84[a]	
MOU period: January 1987–September 1991(249 obs)						
ls_t	−3.15[a]		0.36[b]	0.03	−4.74	−10.85[a]
$lf_t(1)$	−2.89[a]		0.10		−4.77	−17.23[a]
$lf_t(2)$	−2.67[b]	−3.89[a]	0.53[a]	0.05	−4.76	−16.64[a]
SLA 1996 period: January 1996–September 2000 (240 obs)						
ls_t	−1.08	−3.14[a]	0.49[a]	0.32	−3.85	−12.35[a]
$lf_t(1)$	−0.71	−8.41[a]	0.53[a]	0.28	−3.98	−10.02[a]
$lf_t(2)$	−1.28	−3.90[a]	0.55[a]	0.25	−3.35	−15.23[a]
CVD and AD period: August 2001–September 2006 (267 obs)						
ls_t	−1.63	−2.91[a]	1.09[a]	0.13	−4.27	−9.09[a]
$lf_t(1)$	−2.28	−2.98[a]	0.95[a]	0.11	−4.28	−17.41[a]
$lf_t(2)$	−2.33	−2.96[a]	1.05[a]	0.11	−3.96	−16.53[a]
SLA 2006 period: October 2006–October 2015 (453 obs)						
ls_t	−2.26	−2.92[a]	1.78[a]	0.06	−3.46	−20.68[a]
$lf_t(1)$	−2.03	−2.93[a]	1.60[a]	0.06	−3.90	−11.77[a]
$lf_t(2)$	−2.25	−2.86[a]	1.35[a]	0.11	−3.82	−15.88[a]

The number of lags in each test is selected based on the AIC. diff, difference; obs, observations.
[a] Rejection of the null hypothesis at the 5% level of significance.
[b] Rejection of the null hypothesis at the 10% level of significance.

market in Louisiana. Table 2 reports the results of Zivot-Andrews test, which supports the finding of the DF-GLS test that all three variables are stationary at the level of the data. The previous studies in the lumber futures market (Deckard 2000, He and Holt 2004, Hasan and Hoffman-MacDonald 2012), however, reported the presence of unit root in the lumber futures price series. The conclusion was primarily based on the augmented Dicky-Fuller unit root test on small sample data for only a few years.

Given that unit root tests do not produce robust results about the stationary properties of the spot and futures price series, Johansen's cointegation tests (Johansen 1995) might not be appropriate to test the long-run cointegrating relationship between spot and futures prices. In this circumstance, the autoregressive distributed lag (ARDL) bounds testing approach proposed by Pesaran and Shin (1999) and Pesaran et al. (2001) is applicable, as this test does not require the variables to be in a same integration order (Giles 2015). In other words, pretesting for unit roots of individual data series is not a prerequisite for the bounds test of cointegration (Adammer et al. 2015). To implement the

Table 3. ARDL-ECM bounds test.

Bivariate system	ARDL(p^*,q^*)	P value, LM test[a]	F-statistics	t-statistics
Full-sample: January 1980–October 2015				
Model 1: ls_t and $lf_t(1)$	(9, 9)	0.45	10.94[b]	−5.55[a]
Model 2: ls_t and $lf_t(2)$	(7, 8)	0.66	12.86[a]	−6.16[a]
MOU period: January 1987–September 1991				
Model 1: ls_t and $lf_t(1)$	(8, 12)	0.88	3.37	−2.77
Model 2: ls_t and $lf_t(2)$	(6, 12)	0.45	2.22	−2.32
SLA 1996 period: January 1996–September 2000				
Model 1: ls_t and $lf_t(1)$	(1, 2)	0.60	19.16[a]	−7.58[a]
Model 2: ls_t and $lf_t(2)$	(3, 6)	0.68	6.46[a]	−4.08[a]
CVD and AD period: August 2001–September 2006				
Model 1: ls_t and $lf_t(1)$	(7, 4)	0.60	5.43[c]	−4.01[a]
Model 2: ls_t and $lf_t(2)$	(6, 5)	0.63	5.11[c]	−3.90[a]
SLA 2006 period: October 2006–October 2015				
Model 1: ls_t and $lf_t(1)$	(4, 7)	0.47	7.84[a]	−4.70[a]
Model 2: ls_t and $lf_t(2)$	(5, 4)	0.23	6.39[a]	−4.36[a]

Model 1 and Model 2 denote the bivariate system formed by ls_t and $lf_t(1)$ and ls_t and $lf_t(2)$, respectively. The lower and upper bound values for the F-statistics at the 1 and 5% level of significance are 4.94 and 5.58 and 3.62 and 4.16, respectively (Pesaran et al. 2001).
[a] Breusch-Godfrey serial correlation LM test of the residuals at lag 4.
[b] Rejection of the null hypothesis at the 1% level of significance.
[c] Rejection of the null hypothesis at the 5% level of significance.

bounds testing procedure, Equation 2 is reformulated in the following error correction form as

$$\Delta ls_t = \gamma_0 + \pi_1 ls_{t-1} + \pi_2 lf_{t-1}(T) + \sum_{i=1}^{p} \Gamma_{1,i} \Delta ls_{t-i} + \sum_{j=1}^{q} \Gamma_{2,j} \Delta lf_{t-j}(T) + \varepsilon_t \quad (4)$$

Most of the notations in Equation 4 are already defined. γ_0 is a constant term, and ε_t represents white noise errors. The numbers of lagged differences of log-transformed spot and futures prices are denoted by p and q, respectively, which are chosen based on the Akaike information criterion (AIC). The major requirements of this test are that variables should not be $I(2)$ and residuals of the testing model must be serially uncorrelated (Pesaran et al. 2001).

The bounds testing procedure[2] starts with estimating Equation 4 by ordinary least squares and conducting two separate tests on the estimated coefficients of π_1 and π_2. The first test involves an F-test assessing the null hypothesis that $\pi_1 = \pi_1 = 0$ (no cointegration), and the second test is a t-test examining the null hypothesis that $\pi_1 = 0$ (Pesaran et al. 2001). Because both F- and t-statistics under the bounds test do not follow the standard distributions, Pesaran et al. (2001) provided the lower and upper bounds of critical values based on the order of integration of two time series. If the absolute values of the estimated F- and t-statistics exceed the upper bounds of critical values, null hypotheses of no cointegration are rejected.

Table 3 reports the results of the ARDL bounds test between the spot and two futures price series. The AIC selects the optimum lag length of both p^* and q^*. In both bivariate systems, the LM test of the residuals suggests that ARDL estimations are free from serial correlation. Both estimated F- and t-statistics in both combinations of spot and futures prices are well above 1% upper critical values, leading us to conclude that the lumber spot and futures prices are cointegrated. In other words, the bounds test suggests that there exists a long-run equilibrium relationship between the spot and futures prices of softwood lumber. This finding not only supports the theory of the cost of carry model but also refers to the fact that spot and futures prices are driven by the same fundamental factors such as interest rates, macroeconomic news, and shocks (Caporale et al. 2014). Most of the past studies also found a long-run cointegration relationship between the lumber spot and futures prices (Deckard 2000, He and Holt 2004, Hasan and Hoffman-MacDonald 2012), but the study of Manfredo and Sanders (2008) is an outlier which reported that, based on the weekly data from September 2002 to March 2005 only, the lumber spot and futures prices were not cointegrated.

Table 4. Bivariate VEC models: full data sample (1980 W1–2015 W42).

Variable	Model 1	Model 2
Panel A: Unconstrained long-run cointegration relationship		
Spot	1	1
Futures	−0.97 (0.03)[a]	−1.00 (0.04)[a]
Intercept	−0.15 (0.15)	0.025 (0.24)
Panel B: Short-run feedback adjustment coefficients		
α_s	−0.068 (0.02)[a]	−0.057 (0.01)[a]
α_f	0.023 (0.02)	0.002 (0.01)
Panel C: Granger causality on VEC model short-run parameters		
H_0: futures does not cause Spot	219.77[a]	241.40[a]
H_0: spot does not cause Futures	29.31[a]	18.75[b]
Panel D: Price discovery measures		
CFW-spot (θ_s)	0.25	0.03
CFW-futures (θ_f)	0.75	0.97

Model 1 and Model 2 denote the bivariate system formed by ls_t and $lf_t(1)$ and ls_t and $lf_t(2)$, respectively. Values in parentheses are SEs. CFW represents common factor weight.
[a] Rejection of the null hypothesis at the 1% level of significance.
[b] Rejection of the null hypothesis at the 5% level of significance.

The presence of a long-run cointegrating relationship between the spot and futures prices of softwood lumber enables us to evaluate the price discovery process by estimating the two bivariate VEC models. Table 4, Panel A, presents the estimated long-run cointegrating relationship between the spot and futures prices for softwood lumber. The estimated long-run coefficients for the futures prices in both two models are close to unity, which supports the one-to-one relationship between the spot and futures prices as posited by the theory of storage model.

Table 4, Panel B, reports estimated feedback adjustment coefficients ($\alpha = [\alpha_s, \alpha_f]'$) obtained from the dynamic short-run error correction estimation, which explain the adjustment process of spot

Table 5. Price discovery in various episodes of the lumber trade dispute: a bivariate system formed by ls_t and $lf_t(2)$.

Variable	Softwood lumber trade dispute periods			
	MOU	SLA 1996	CVD and AD	SLA 2006
Panel A: Unconstrained long-run cointegration relationship				
Spot		1	1	1
Futures		−1.34 (0.09)[a]	−1.55 (0.08)[a]	−1.20 (0.07)[a]
Intercept		2.00 (0.55)[a]	3.15 (0.46)[a]	1.13 (0.38)[a]
Panel B: Feedback adjustment coefficients				
α_s		−0.171 (0.05)[a]	−0.099 (0.03)[a]	−0.085 (0.03)[a]
α_f		0.047 (0.04)	0.080 (0.04)[a]	0.061 (0.03)[b]
Panel C: Granger causality on VEC model short-run parameters				
H_0: futures does not cause spot		0.47[a]	0.28[a]	50.47[a]
H_0: spot does not cause futures		−0.001	0.04	9.34[b]
Panel D: Price discovery measures				
CFW-spot (θ_s)		0.22	0.45	0.42
CFW-futures (θ_f)		0.78	0.55	0.58

MOU period: January 1987–September 1991; SLA 1996 period: January 1996–September 2000; CVD and AD period: August 2001–September 2006; SLA 2006 period: October 2006–October 2015. Values in parentheses are SEs. CFW, common factor weight.
[a] Rejection of the null hypothesis at the 1% level of significance.
[b] Rejection of the null hypothesis at the 5% level of significance.

and futures prices toward the long-run equilibrium. The estimated adjustment coefficients for the spot market (α_s) in both models are statistically significant, but both α_f estimates are statistically insignificant. Two adjustment parameters, having different signs, indicate the direct convergence to the long-run relationship. The magnitude of the adjustment coefficient is also relatively higher in the spot market, which implies that the short-term disequilibrium created by shocks and news are corrected mainly in the spot market. Because only the adjustment parameter associated with the spot price is statistically significant in both models, it can be inferred that the spot price of softwood lumber follows the price movements originating in the futures market but not the other way around (Adammer et al. 2015). Further, the overall speed of adjustment ($|\alpha_s| + |\alpha_f|$) is higher in Model 1 (0.091) than in Model 2 (0.059), suggesting that stronger feedback convergence occurs in the first nearby futures contracts than in second nearby futures. Our results in the feedback adjustment coefficients are consistent with the recent studies in other commodity markets (Kavussanos and Nomikos 2003, Caporale et al. 2014, Adammer et al. 2015).

Table 4, Panel C, displays the results of Granger causality tests in short-run cross-market coefficients. In both models, the Granger causality test rejects the null hypothesis of no short-run causality from futures to spot prices. Similarly, the null hypothesis that the spot price does not Granger-cause the futures price to be also rejected at the 1% level. Hence, it can be concluded that there exists a two-way short-run feedback relationship between the spot and futures prices in the US lumber market. In other words, the lagged values of one price series help predict another price series in the lumber market. The bidirectional causality also implies a changing pattern of leads and lags over time so that the lagged values of both price series help predict the spot and futures prices in the short run (Silvapulle and Moosa 1999).

Table 4, Panel D, reports the estimated common factor weights that quantify the relative contribution of each market to the price discovery of softwood lumber. In Model 1, around 75% of the price discovery takes place in the futures market and the remaining 25% in the spot market. The relative contribution of the spot market to price discovery tends to decline rapidly as the second nearby futures contract is taken into account. In Model 2, the contribution of the lumber futures market to price discovery is 97%, indicating that the futures market plays a dominant role in price discovery of softwood lumber. Our findings are nearly identical to the results reported by Caporale et al. (2014), who found that in the crude oil market, both spot and futures contribute to price discovery in the scenario of the near-to-maturity futures contract, but price discovery takes place only in the futures market if the time-to-delivery of the contracts increases. Silverio and Szklo (2012), Shrestha (2014), and Adammer et al. (2015) also found that the futures markets play a dominant role in price discovery of energy and agricultural commodities.

Price Discovery in Various Episodes of the Lumber Trade Dispute

As Table 2 depicts, all three unit root tests conclude that both spot and futures price series during the periods of SLA 1996, CVD and AD, and SLA 2006 are found to be nonstationary at the level of the data and stationary at the first difference, suggesting an integration of order 1. In the MOU period, the unit root results are inconclusive as the results of the Zivot-Andrews test are different from the findings of the DF-GLS unit root test. Whereas the KPSS test reports similar unit root properties of the variable for full sample and various trade dispute periods, the Zivot-Andrews test reports completely opposite results for full sample and trade dispute periods (Table 2). For the full sample period, the Zivot-Andrews test suggests that all variables are stationary at the level of the data, but it suggests an integration of order 1 for all variables during four subsample periods.

Furthermore, Table 3 reports the results of the ARDL-error correction model (ECM) bounds cointegration test between the spot and futures prices during these trade dispute episodes. In the MOU period, both the *F*-test and *t*-test reveal that the spot and futures price series are not cointegrated, indicating no long-run cointegrating relationship between the lumber spot and futures markets. However, both models of the bivariate system formed by spot and futures prices are found to be cointegrated during the SLA 1996, CVD and AD, and SLA 2006 periods. Table 5 reports the relationship between spot and the second nearby futures prices in the trade dispute periods. Because the results are quite similar qualitatively for first nearby futures contracts, we only report the results of Model 2 here. The long-run cointegrating estimates reveal that a 1% increase in the futures price leads to an increase in the lumber price in the spot market of more than 1% (Table 5, Panel A).

In terms of the short-run adjustment parameters, α_f estimates in the two SLA and CVD and AD periods are negative and statistically significant at 1% (Table 5, Panel B). The α_s estimates are positive and also statistically significant during the CVD and AD and SLA 2006 periods. This indicates that adjustments occur in both spot and futures markets to offset the disequilibrium in the system created by short-term shocks and new information during the last two trade dispute periods. In the last three periods, the overall speed of adjustment is quite faster in the SLA 1996 period; any short-run disequilibrium is corrected by around 22% (0.17 ± 0.047%) each week.

The Granger causality tests on the short-run coefficient estimates of lagged differenced terms reveal that in the periods of SLA 1996 and CVS and AD, only the lumber futures price Granger-causes the spot price, but not vice versa (Table 5, Panel C). In these two periods, only the null hypothesis that the futures price does not Granger-cause the spot price is rejected, indicating that there is unidirectional feedback running from futures to the spot market. The short-run causality during the SLA 2006 period is, however, bidirectional. The lagged values of both futures and spot prices help predict another price series of softwood lumber. Moreover, Table 5, Panel D, presents the estimated common factor weights corresponding to the last three trade dispute episodes. Consistent with the scenario of full data, in the period of 1996 SLA, the futures market for softwood lumber plays a dominant role in price discovery. During the last two trade dispute periods, both markets play an important role in price discovery with a slight edge by the futures market. In the CVD and AD and SLA 2006 periods, 55 and 58% of price discovery takes place in the futures market, respectively.

Conclusions

This study examines the relative contributions of spot and futures markets to the price discovery of softwood lumber. Unlike previous studies that employed a relatively small data sample, we investigate the price relationship based on the weekly data from 1980 to 2015. We find that lumber futures and spot prices are cointegrated, indicating a long-run equilibrium relationship between the futures and spot markets in terms of pricing behavior. The futures market for softwood lumber is found to have a significant role in price discovery. In the case of the futures prices constructed from the second nearby contracts, almost of all price discovery takes place in the futures markets, and the contribution of the spot market is minimal.

The results on market integration and comovement in prices have useful implications to hedgers in the futures exchange. Because spot and futures markets are cointegrated and one of them is considered dominant in the process of reflecting information, another market (spot or futures) possibly adjusts quickly to reestablish the long-run equilibrium state of no arbitrage between them (Silvapulle and Moosa 1999). Moreover, a higher contribution of futures markets in the process of price discovery implies that financial factors and market agents play a vital role in driving the lumber price in the United States.

As for the futures-spot price linkages in the various episodes of the United States-Canada softwood lumber trade dispute, we find that the results are somewhat different from the scenario of the full data model. All three tests reports the presence of unit root in all variables. In the MOU period, no long-run cointegation is detected between the futures and spot prices, implying market inefficiency in the US lumber market. A finding of no cointegration also indicates that futures and spot markets do not share the same generating mechanism and act as if they represent two different underlying assets. On the other hand, the spot market is also found to have an important role in the price discovery process, especially in CVD and AD and SLA 2006 periods. The futures markets, however, still leads in price discovery during these trade dispute periods.

Although this study sheds some light on the contributions of futures and spot markets to price discovery in the US lumber market, further analyses could evaluate the forecasting performance and predictive contents of lumber futures. Our analysis could be extended by estimating time-varying price linkages between lumber futures and spot markets over the years. Because both futures and spot price data are readily available for several decades, investigating a role of the futures market in risk management could also be a worthwhile endeavor.

Endnotes

1. This rollover approach is identical to Quandl's (2015) continuous front month contract #1.
2. Giles (2015) explained the stepwise procedure of performing the ARDL bounds test in EViews 9.

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