The Role of CME Softwood Lumber Futures Contracts in Price Risk Management

by

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Abstract

Cointegration analysis techniques are used to test the forward rate unbiasedness hypothesis (FRUH) with respect to softwood lumber cash (spot) and futures markets. Structural restrictions are imposed to explicitly examine long-run dynamic relationships between the two markets. The results provide empirical evidence that spot and futures markets for U.S. softwood lumber exhibit a long-run equilibrium that functions within the theoretical structural restrictions of the FRUH. Hence, the necessary conditions for price risk management appear to be met. The results also suggest that spot prices are weakly exogenous in the cointegrating relationship. In essence, futures market adjustments appear to be conditional to shocks in spot markets while spot markets do not seem to respond to shocks in futures markets. This finding is critical in the sense that, at least in the case of softwood lumber, the spot market appears to be the dominant source of price discovery with futures prices responding to new spot market information by adjusting to changes in spot market risk expectations.

Softwood lumber futures contract volume traded on the Chicago Mercantile Exchange (CME) amounts to nearly 20 billion board feet annually, the equivalent of 2/5s annual U.S. consumption (Figure 1).

Figure 1. U.S. softwood lumber consumption v. CME softwood lumber futures contract volume, 1983-1998.

The dual roles of price risk management and price discovery often are presented as being social benefits derived from organized trading in futures markets. In commodity futures markets, fulfillment of the first role is predicated on the assumption that the series move together in a long-run equilibrium relationship. Fulfillment of the second role requires that futures prices and spot prices interact in a way such that futures prices tend to lead spot prices, as new market information becomes available. Recent advances in cointegration analysis techniques provide a new basis from which to examine these explicit relationships between spot and futures commodity markets. Models of cointegration between spot and futures prices are based on arbitrage theory. In commodity markets, the no-arbitrage asset pricing model assumes that a rational market participant should be indifferent between purchasing a commodity in the spot market at time (t) and purchasing a risk adjusted futures contract for that commodity at time (t-k) with a maturity date of time (t). If this were not true, opportunities for risk free profit would exist. The theoretical implication is that a long-run equilibrium must exist between spot and futures prices for the markets to be operating in an economically efficient manner. This long-run equilibrium relationship is referred to in the literature as the forward rate unbiasedness hypothesis (FRUH).

Two predominant theoretical models of cointegration between spot and futures prices have been used in empirical research to test the FRUH. The first model is between the current forward rate, \( F_t \), and the current spot rate, \( S_t \), referred to in the literature as \( (F_t, S_t)' \). The second model is between the current forward rate, \( F_t \), and the expected future spot rate, \( S_{t+1} \), referred to in the literature as \( (F_t, S_{t+1})' \). Variations of both models include adding an interest rate series to account for a time varying risk premium, where the triangular representation has, at most, a single cointegrating relationship.

The FRUH requires that three conditions be met: (i) the spot rate and the forward rate must be

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cointegrated; (ii) the coefficients of the cointegrating vector must be restricted to (1, -1); and (iii) the residuals in the cointegrating regressions must be white noise (Norrbin and Reffett 1996). As Engel (1996) points out, the two predominant theoretical models of cointegration between spot and futures prices are equivalent in terms of restrictions imposed by the FRUH. Under the condition $F_t$ and $S_t$ are both integrated of order one, denoted as $I(1)$, if $F_t$ and $S_t$ are cointegrated with a single cointegrating vector $(1, -1)$, then $F_t$ and $S_{t+1}$ must be cointegrated with a cointegrating vector $(1, -1)$. Zivot (1997) argues that tests of market efficiency based on cointegration between $F_t$ and $S_t$ are more reliable than tests based on cointegration between $F_t$ and $S_{t+1}$ because “...the implied model for $(F_t, S_{t+1})$’ is nonstandard and does not have a finite VAR representation”, where VAR refers to a vector autoregression model.

Empirical research testing specific agricultural commodity markets for cointegration between spot and futures price series has produced mixed results with respect to market efficiency. For example, Schroeder and Goodwin (1991) failed to find cointegration between spot and futures markets for U.S. live hogs using the Engle-Granger (1987) bivariate method. Zapata and Fortenbery (1996) found evidence of cointegration between Chicago corn and soybean spot prices, nearby futures prices, and interest rates for most years examined. Fortenbery and Zapata (1997), then Thraen (1999) examined the domestic cheddar cheese spot and futures markets for long-run equilibrium using Johansen’s Maximum Likelihood Estimation (MLE) procedure (Johansen 1988; Johansen and Juselius 1990, 1992). These separate studies reached opposite conclusions with respect to cointegration between cheddar cheese spot and futures markets.

Methods

Time series (Figure 2) consist of a monthly softwood lumber spot price series and a monthly softwood lumber futures price series for the time period from January 1983 through December 1998 ($N = 192$). The spot price series is Western spruce-pine-fir, kiln dried, 2x4, random length, base price, as reported in the Random Lengths Yearbook (1992, 1998). The futures price series is the nearby CME lumber futures contract settlement price (refer to the Appendix for details). The starting points of both series represent the maturity month of the first CME lumber futures contract. Nearby futures monthly mid-point settlement prices are used. Nearby futures settlement prices provide a near constant-maturity rate or “continuation basis” (Ferris 1998). Both series are inflation adjusted using the implicit GDP deflator. Natural logarithms are used in order to reduce problems normally associated with heteroskedasticity.

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A three-stage approach is used for analysis of the $(F_t, S_t)$ model. First, each series is tested for unit roots in the levels and for stationarity in the first-differences. Second, Johansen’s MLE procedure is used for cointegration analysis to determine if a long-run equilibrium exists between spot and futures prices for softwood lumber. Finally, structural restrictions are imposed on the vector error correction model (VECM) in order to test the long-run dynamic relationships between spot and futures prices. All statistical analyses are conducted using analytical subroutines included in the RATS and CATS econometrics software programs or with add-on procedures available online from the RATS website at [http://www.estima.com/].

Johansen’s MLE procedure is a $p$-dimensional VAR($k$) process with Gaussian errors, where $p$ = the number of variables in the model and $k$ = the lag length. The notation used in this portion of the paper follows Hansen and Juselius (1995). The full general form VECM representation of $(F_t, S_t)$’ is given by

$$
\Delta Z_t = \Gamma_1 \Delta Z_{t-1} + \ldots + \Gamma_{k-1} \Delta Z_{t-k+1} + \Pi Z_{t-1} + \mu + \delta t + \psi D_t + \varepsilon_t, \quad t = 1, \ldots, T \quad (1)
$$

where $\Delta$ is a difference operator, $Z_t$ is a ($p \times 1$) vector of $(F_t, S_t)'$, $\Gamma_1$ through $\Gamma_{k-1}$ are coefficient matrices for the lagged differenced variables, $\Pi$ is the reduced form error correction term consisting of a matrix of

![Figure 2. Spot and futures monthly series in constant 1992 dollars.](image-url)
long-run coefficients, \( \mu \) is a vector of intercept terms, \( \delta \) is a deterministic trend coefficient, \( \psi \) is a dummy variable coefficient, \( D_t \) is a vector of dummy variables, i.e., deterministic seasonals, mean shifters, slope shifters, or, in some cases, stochastic exogenous variables, and \( \varepsilon_t \) is a vector of error terms assumed to be \( \text{iid}(0, \Omega) \), i.e., the error terms are normally and independently distributed with an expected mean of zero and \( \Omega \) has the elements \( \sigma_{ij} \) (i,j = F, S). It must be noted that either \( \mu \) or \( \delta \) can be restricted to the error correction term. If \( \delta \) is restricted to the error correction term, \( \mu \) is automatically included in the model thus, a non-zero mean is allowed. Expectation of a negative intercept is reasonable because \( F_t \) is surmised to trade at a discount to \( S_t \) in the long run.

The hypothesis of cointegration is formulated as a reduced rank (r) of the \( \Pi \) matrix. Under the assumption of cointegration where \( \Pi \) has \( r=1 \), the \( \Pi \) matrix can be decomposed into a matrix of speed-of-adjustment coefficients, \( \alpha \), and a matrix of cointegrating vectors, \( \beta \), such that \( \Pi = \alpha \beta' \). The cointegrating relation (II) in equation (1) is stationary, often interpreted as the long-run equilibrium for the levels (\( Z_t \)). If \( \beta' = Z_{t-1} \neq 0 \), it is interpreted as a long-run equilibrium error. Further, \( \alpha \beta' \) is a measure of the average speed-of-adjustment towards long-run equilibrium. Imposing the theoretical FRUH restrictions \( \beta' = (1, -1) \) on \( (F_t, S_t)' \), restricting the trend coefficient to the error correction term, and dropping the dummy variables, the components of the VECM may be expressed as

\[
\Delta F_t = \Gamma_1 \Delta F_{t-1} + \ldots + \Gamma_{k-1} \Delta F_{t-k+1} + \alpha_F \left( F_{t-1} - S_{t-1} + \delta t_{t-1} \right) + \mu_F + \varepsilon_{Ft}, \quad (2a)
\]

\[
\Delta S_t = \Gamma_1 \Delta S_{t-1} + \ldots + \Gamma_{k-1} \Delta S_{t-k+1} + \alpha_S \left( F_{t-1} - S_{t-1} + \delta t_{t-1} \right) + \mu_S + \varepsilon_{St}, \quad (2b)
\]

As shown by Johansen (1992), Norrbin and Reffett (1996), and Zivot (1997), testing the VECM for weakly exogenous variables is accomplished by individually restricting the speed-of-adjustment coefficients, \( \alpha_F \) and \( \alpha_S \), to a value of zero. At one end of the continuum, if \( \alpha_F = 0 \) and \( \alpha_S \neq 0 \), equation (2a) is dropped and spot market adjustments become conditional to shocks in futures markets. In this case, efficient estimation of the cointegrating parameters can be made from the single equation conditional error correction model (ECM)

\[
\Delta S_t = \Gamma_0 \Delta F_t + \Gamma_1 \Delta Z_{t-1} + \ldots + \Gamma_{k-1} \Delta Z_{t-k+1} + \alpha_S \left( F_{t-1} - S_{t-1} + \delta t_{t-1} \right) + \mu_S + \varepsilon_{St}, \quad (3a)
\]

where \( \Gamma_0 \Delta F_t \) is the conditional term with respect to \( \Delta S_t \) and \( \varepsilon_{St} \) is uncorrelated with \( \varepsilon_{St} \).

At the other end of the continuum, if \( \alpha_S = 0 \) and \( \alpha_F \neq 0 \), equation (2b) is dropped and futures market adjustments become conditional to shocks in spot markets. In this case, efficient estimation of the cointegrating parameters can be made from the single equation conditional ECM

\[
\Delta F_t = \Gamma_0 \Delta S_t + \Gamma_1 \Delta Z_{t-1} + \ldots + \Gamma_{k-1} \Delta Z_{t-k+1} + \alpha_F \left( F_{t-1} - S_{t-1} + \delta t_{t-1} \right) + \mu_F + \varepsilon_{Ft}, \quad (3b)
\]

where \( \Gamma_0 \Delta S_t \) is the conditional term with respect to \( \Delta F_t \) and \( \varepsilon_{Ft} \) is uncorrelated with \( \varepsilon_{Ft} \). Of course, it is possible that both \( \alpha \) values \( \neq 0 \). In this case, both variables respond to shocks in either of the markets and the two-equation model, (2a) (2b), is appropriate.

**Results and Discussion**

Unit root tests are conducted using the Augmented Dickey-Fuller (ADF) t-test (Dickey and Fuller 1981) with Hamilton’s (1994) critical values, the Phillips-Perron (PP) Z-test (Phillips and Perron 1988), and the KPSS (Kwiatkowski, Phillips, Schmidt, and Shin 1992) unit root test. **Table 1** presents the results of the unit root tests for both level and first-differenced series based on regressions that include a constant. The null hypothesis (Ho) for the ADF and PP tests is that of having a unit root, or being \( I(1) \). The null hypothesis (Ho) for the KPSS test is that of being stationary or \( I(0) \). The appropriate number of lags is determined for each series and condition (i.e. levels or first-differenced) using Akakie Information Criterion (AIC). The levels for each series tested to be first order integrated or \( I(1) \) while the first-differences of each series tested to be stationary or \( I(0) \) at the 1 percent significance level using one-tailed tests. The selected lag lengths imply a seasonal component in both monthly time series approximating an annual unit root.

After verifying the nonstationarity of the variables, testing for cointegration in the \( (F_t, S_t)' \) model is accomplished using Johansen’s MLE procedure. Results of the Trace and \( \lambda \)-Max tests are presented in **Table 2**. Both tests are designed to determine the number of cointegrating relationships or rank \( r \) between a set of variables with a minimum value of \( r = 0 \) and a maximum value of \( r = p-1 \) where \( p \) is the total number of variables in the model. The null hypothesis (Ho) for the Trace test is \( r = p-1 \). The null hypothesis (Ho) for the \( \lambda \)-Max test is \( r = 0 \) through \( r = p-1 \). The null hypotheses differ in the sense that the
The \(\lambda\)-Max test has more power to discern that actual value of \((r)\) relative to the Trace test. Critical values are from Johansen and Nielsen (1993). The Trace test rejects the null hypothesis of \(r = 0\) at the 10 percent significance level while the \(\lambda\)-Max test rejects the null hypothesis of \(r = 0\) at the 5 percent significance level. Based on the results of the Trace and \(\lambda\)-Max tests, the variables are found to share one cointegrating vector.

Having established the cointegrating rank =1, structural restrictions are applied to the model based on theoretical expectations in order to test the FRUH. That is to say, \(\beta(F_t, S_t)' = (1, -1)\) is imposed. Simulations are run, first restricting \(\alpha_F\) to zero then, restricting \(\alpha_S\) to zero. In terms of model fit as measured by the significance levels of the estimated parameters, the most plausible result is presented in Table 3. The fully restricted model is found to contain significant intercept \((\mu_F)\) and trend \((\delta t, t - 1)\) terms with the trend being restricted to the cointegrating space. The \(\Gamma\) coefficients for the lagged values of \(F_t\) and \(S_t\) are significant from \(t - 1\) through \(t - 4\) with mixed results from \(t - 5\) through \(t - 11\). In terms of overall model fit, the joint null hypotheses, \(\beta' = (1, -1)\) and \(\alpha_S = 0\), are not rejected at the 10 percent significance level \((p = .110)\) using the Likelihood-Ratio (LR) test. The restricted model results indicate spot and futures softwood lumber markets meet the long-run expectation of \(\beta' = (1, -1)\). In addition, Lagrange-Multiplier (LM) tests for first and fourth order autocorrelation indicate no significant autocorrelation with p-values of 0.45 and 0.22 respectively. Hence, the single equation conditional ECM (3b) appears to meet all necessary conditions imposed by the FRUH.

--- Table 1. ADF, PP, and KPSS test results for unit roots. ---

<table>
<thead>
<tr>
<th>Series</th>
<th>Lags</th>
<th>ADF (t-test)</th>
<th>PP (Z-test)</th>
<th>KPSS ((\eta(\mu)))</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>(F_t)</td>
<td>11</td>
<td>-1.34</td>
<td>-4.38</td>
<td>1.39***</td>
<td>(I(1))</td>
</tr>
<tr>
<td>(S_t)</td>
<td>12</td>
<td>-1.74</td>
<td>-7.85</td>
<td>1.22***</td>
<td>(I(1))</td>
</tr>
</tbody>
</table>

--- Table 2. Trace and \(\lambda\)-Max cointegration test results for \((F_t, S_t)'\). ---

<table>
<thead>
<tr>
<th>Ho:</th>
<th>Ha:</th>
<th>Eigenvalue</th>
<th>LR</th>
<th>90%CV</th>
<th>95%CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>(r = 0)</td>
<td>(r &gt;1)</td>
<td>0.0759</td>
<td>24.34*</td>
<td>22.95</td>
<td>25.47</td>
</tr>
<tr>
<td>(r = 1)</td>
<td>(r &gt;1)</td>
<td>0.0547</td>
<td>10.13</td>
<td>10.56</td>
<td>12.39</td>
</tr>
</tbody>
</table>

--- Table 3. Estimates of the single equation conditional ECM for \((F_t, S_t)'\) imposing \(\beta = (1, -1)\) and \(\alpha_S = 0\). ---

<table>
<thead>
<tr>
<th>(\mu) (t-value)</th>
<th>(\delta t, t - 1) ((\sigma^2))</th>
<th>(\alpha_F) (t-value)</th>
<th>(R^2)</th>
<th>LR (p-value)</th>
<th>LM(1) (p-value)</th>
<th>LM(4) (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.016 (-1.178)</td>
<td>-0.001 (0.000)</td>
<td>-0.466 (-1.721)</td>
<td>0.508</td>
<td>4.46 (0.11)</td>
<td>135.421 (0.45)</td>
<td>5.708 (0.22)</td>
</tr>
</tbody>
</table>

\(\Gamma\) coefficients are not shown.
Since the data series were transformed to natural logarithms prior to analysis, the ECM coefficients, $\alpha$ and $\beta$, are interpreted as relative elasticities. Given the restriction of $\beta' = (1, -1)$, a long-run elasticity of unity between $F_t$ and $S_t$ cannot be rejected. The speed-of-adjustment measure for $F_t = \alpha F_t \beta' F_t = -0.466$ (t-value = -1.721) indicating that $F_t$ does not return to its long-run equilibrium position within a single monthly reporting period. Since the elasticity of the forward rate is directly related to the persistence of interest rate differentials now measured by $\alpha F$, stability of the ECM requires that $| \alpha F \beta' F | < 1$. Thus, the highly persistent continuation basis is consistent with the FRUH.

Figure 3 depicts the disequilibrium error correction process for $(F_t, S_t)'$. Figure (3a) plots $\beta' F_t$, the actual disequilibrium function including all short-run dynamics. The function is stationary with a negative mean as allowed for by restricting the trend to the cointegration space. Figure (3b) depicts $\beta' R_t$ where $R_t$ represents the residuals of the concentrated likelihood function or reduced rank regression.

Figure 3. Disequilibrium error process in the fully restricted error correction model.

$\beta' R_t$ is the series actually tested for stationarity and determines the rank of the $\Pi$ matrix in the MLE procedure. This series is corrected for the short-run effects and provides a “clean” view of the disequilibrium. While Figure (3a) indicates a negative intercept in the long-run equilibrium relationship, Figure (3b) reveals that nearby futures contracts traded at a premium to spot markets in the early 1990s indicating the expectation of increasing spot prices. However, in long-run equilibrium, nearby futures contracts tend to trade at a discount to current spot prices.

Implications for Price Risk Management

Within the framework of this analytical approach, the results provide empirical evidence that spot and futures markets for softwood lumber exhibit a long-run equilibrium that operates within the theoretical expectation of the FRUH. The markets appear to operate in a marginally efficient manner, providing the necessary conditions for price risk management. The fact that Ho: $\alpha S = 0$ cannot be rejected in the fully restricted model suggests the cointegrating relationship is one-sided. Futures price adjustments appear to be conditional to shocks in spot markets while spot markets do not seem to respond to shocks in futures markets. The dynamic process of the spot-futures softwood lumber system (equation 3b) can then be described as exogenous “news” affecting the spot rate which causes a temporary disequilibrium between the spot and forward rate that is eventually eliminated by adjustments to only the forward rate. This finding is critical in the sense that, at least in the case of softwood lumber, the spot market appears to be the dominant source of price discovery with futures prices responding to new market information by adjusting to changes in spot market prices and risk expectations. The question of how this information can be used to develop optimal hedging ratios for individual futures contracts needs to be addressed in future work.

Literature Cited


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**Appendix. CME Lumber Contract Specifications**

The CME initiated trading of softwood lumber futures contracts in April 1982. Individual contracts have a life of nine months reaching maturity in January, March, May, July, September, and November of each year. The CME lumber contract represents softwood lumber produced from various species of spruce, pine, and fir grown in the Western U.S. and the western provinces of Canada. The majority of this lumber is used for new home construction and home improvement. Historically, each CME lumber contract represented 80,000 board feet (one railroad flatcar) of wrapped, kiln-dried 2x4s in random lengths from 8 to 20 feet long, loaded on track at the producing Pacific North West or Southwestern Canada sawmill. Beginning with the launch of the January 2000 contract that started trading on April 12, 1999, the individual contract volume was increased from 80,000 board feet to 110,000 board feet.