Asymmetric price transmission in the wood products sector in the Southern United States

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Abstract

Prices play a key role in the market economy. Asymmetric price transmission (APT) is a price phenomenon that is ignored in the forest sector, particularly in the United States, although it has been the subject of considerable attention in the agricultural sector or other sectors. In this study, the presence of price transmission asymmetry for wood products sector in the Southern United States is investigated. The Error Correction Model (ECM) is used with quarterly prices at two stages from standing timber to delivered timber and to lumber markets and vice-versa from 1977 to 2008. All prices are found to be nonstationary, and there is evidence of Engle-Granger (EG) co-integration for six pairs of price series. The estimated results of the ECM-EG for APT reveal that the asymmetric price transmission exists in the four pairs of price series in the long and short term. Moreover, the existence of positive APT that squeezes the margin more rapidly than it stretches the margin is widely expected in this study. Meanwhile, the negative APT that is not usually observed in the past does exist in this study.

Key Words: wood market, Error Correction Model, asymmetry price transmission

INTRODUCTION

The Southern U.S. states have long been a timber production base, and most of the forestlands (i.e., 70%) in the South is owned by nonindustrial private forest (NIPF) landowners (Smith, et al.). A fundamental question is whether the price transmission in the supply chain from NIPF landowners to loggers and processors is symmetric. Traditionally, economic theory has assumed that prices adjust rapidly to equate demand and supply (Brännlund,1991). Thus, upstream price change (e.g. sawtimber price) symmetrically triggers downstream price change (e.g. lumber price), other things being equal. The latest literature provides evidence of asymmetric price transmission (APT) in the agriculture, gasoline, and financial markets (Meyer and von Cramon-Taubadel, 2004). The presence of APT is also coded in the wood sector in the case of Greece (Koutroumanidis, Zafeiriou and Arabatzis, 2009). Whether asymmetric price transmission exists in the wood products industry in the Southern U.S. is unclear.

In addition, there has been widespread concern about market efficiency and welfare distribution for policy analysis. If the APT occurs in the wood products industry in the Southern U.S., most of previous public programs need to be revisited. For example, the cost-share program that intended to reduce costs in upstream stage might not benefit consumers or users of the lumber market efficiently. Likewise, the monetary policy that kept low interest rate to stimulate the housing market might not benefit logging sector or even landowners because the margin might be squeezed by the manufacturing processors.

Moreover, most previous studies have not examined data stationarity, and the static structural parameter estimation might have the problem of spurious regression if some series of data are not stationary. To overwhelm this problem, an error correction model (ECM) can be employed (Harris and Sollis, 2003). Recently a few studies have examined wood sector (Zhou and Buongiorno, 2005**;** Hänninen, Toppinen and Toivonen, 2007**;** Koutroumanidis, Zafeiriou and Arabatzis, 2009). For example, Koutroumanidis, Zafeiriou and Arabatzis (2009) investigates asymmetry in the price transmission mechanism between the producer and the consumer prices in the sector of forest products in Greece. However, no such work has been performed in the wood products industry in the Southern U.S.

The objective of this study is to investigate the presence of price transmission asymmetry for the wood products sector in the Southern United States. The Error Correction Model (ECM) is used with quarterly prices at two stages from standing timber to delivered timber and to lumber markets from 1977 to 2008. This study will reveal the magnitude and speed of the price transmission in the wood products sector, furthermore, provide an understanding of market information efficiency and welfare distribution between timber suppliers, processors and consumers. This study also will help policy makers in designing appropriate programs in helping landowners, loggers and wood products industry improve their competitiveness in challenging market conditions.

LITERATURE REVIEW

Historically, economic theory states that economic equilibrium is simply a state where economic forces are balanced and a market price is established through competition such that quantity demanded and quantity supplied are equal. Over the past two decades, the literature has developed which presents the evidence of the presence of asymmetric price transmission (APT) in agriculture, gasoline market, and financial market (Meyer and von Cramon-Taubadel, 2004). Early studies seek to explain the price phenomenon by identifying APT and thus the possible policy intervention. Estimation techniques are the strong focus on agricultural markets (Houck, 1977; Ward, 1982; Wolffram, 1971). These can be referred to as the 'pre-cointegration' approaches (Meyer and von Cramon-Taubadel, 2004). It is clear the estimation might have the problem of spurious regression if some series of data are not stationary and cointegrated. The first attempt to employ co-integration techniques in testing for APT is von Cramon-Taubadel and Fahlbusch (1994). Since then, they have been used extensively in the study of APT (von Cramon-Taubadel, 1998; Balke, Brown and Yücel, 1998; Frost and Bowden, 1999).

The relation between stumpage prices and wood product prices has been examined in several studies. Among these early studies, Haynes (1977) analyzes the link between regional stumpage and lumber markets with a theoretically derived demand model. When this model is applied to empirical data, the derived demand function for stumpage is found to be less elastic than the lumber demand function. Regional estimates of this relationship are found to differ widely with the South being more elastic than the West.

Zhou and Buongiorno (2005) investigates the prices of products at different stages of manufacturing with quarterly prices of softwood stumpage in the U.S. South and national prices of forest products from 1977 to 2002. All prices are found to be nonstationary, and there is no evidence of co-integration between prices. Vector autoregressive models show that there is a one-to-one permanent positive response of the southern sawtimber stumpage price to a permanent change in the national lumber price. There is also a one-third permanent positive response of the national paper price to a permanent change in the national pulp price. There is no relation between regional pulpwood prices and national pulp or paper prices. When price transmission is significant, the full adjustment takes about two years.

For European markets, Hänninen, Toppinen and Toivonen (2007) analyzes the mechanism by which economic changes in European consumer markets and sawnwood prices pass through to exporters' domestic roundwood prices. Results based on seemingly unrelated regression analysis indicate that price transmission exhibits similarities between old and new EU member countries. Overall development in both sawnwood and sawlog prices displays convergence in the study period and indicates that deepening integration in the European markets is also detectable in the forest sector.

The latest study, Koutroumanidis, Zafeiriou and Arabatzis (2009) examines asymmetry in the price transmission mechanism between the producer and the consumer prices in the sector of forest products in Greece. In particular, the research is focused on the roundwood of long length. The Johansen co-integration and two dynamic models (the Error Correction Model and LSE−Henry general to specific model) are estimated. The existence of a long-run relationship between the producers and the consumers in the Greek round wood market is detected. The consumer price Granger causes the producer price whereas the reverse is not valid, so the existence of asymmetry in the price transmission mechanism within the round wood market is confirmed.

Overall, asymmetry in price transmission has been examined in numerous issues in the agriculture, gasoline market, and financial market (Meyer and von Cramon-Taubadel, 2004). Applications related to the U.S. wood products industry have been limited. In particular, to our best knowledge, no study has been conducted to evaluate APT in the wood products industry in the Southern U.S.

RESEARCH METHODS

Prices drive resource and welfare allocation and price transmission integrates markets vertically (Meyer and von Cramon-Taubadel, 2004). Of special interest are those processes that are referred to as asymmetric price transmission (APT). APT is the pricing phenomenon occurring when downstream prices react in a different manner to upstream price changes, depending on the characteristics of prices or their changes. To better understand where the asymmetric transmission occurs, the vertical market linkages are dissected into two stages: Stage I is from standing timber prices to delivered timber prices and Stage II is from delivered log prices to the lumber market. In this study, the asymmetry of price transmission is examined for the timber and wood products market in the southern United States using an approach: Error Correction Model (ECM).

The ECM approach

The approach takes into consideration the time series properties of data. Applications of the ECM in testing for APT include von Cramon-Taubadel (1998) and Grasso and Manera (2007). The potential for spurious regression in the case of asymmetry tests can be solved by incorporating asymmetric adjustment terms so it provides a more appropriate specification for testing APT. Following the previous studies' framework (Granger and Lee, 1989; von Cramon-Taubadel and Loy, 1999), a dynamic asymmetric model can be presented:

$$\Delta P_{dt} = \beta_0 + \sum_{i=1}^{n_1} \beta_{1i} \Delta P_{dt-i} + \sum_{i=0}^{n_2} \beta_{2i}^{+} \Delta P_{ut-i}^{+} + \sum_{i=0}^{n_3} \beta_{2i}^{-} \Delta P_{ut-i}^{-} + \beta_3^{+} \upsilon_{t-1}^{+} + \beta_3^{-} \upsilon_{t-1}^{-} + \eta_t \qquad (1)$$

where n_1 and n_2 represent the length of the lags with regard to rising and falling prices series, respectively, and $\upsilon_t = P_{dt} - \phi_0 - \phi_1 P_{ut}$ (residuals from the co-integration). A formal test of the symmetric hypothesis is:

$$\begin{aligned} H_0 : \sum_{i=0}^{n_2} \beta_{2i}^{+} &= \sum_{i=0}^{n_3} \beta_{2i}^{-} \text{ in the short term} \\ \beta_3^{+} &= \beta_3^{-} \text{ in the long term} \end{aligned} \qquad (2)$$

The Wald test is applied to the examination of the equality validity.

Before implementing APT test, the stationarity property of individual series needs to be examined by the Augmented Dickey-Fuller (ADF) test (Enders, 1995, pp.433) because the data used in this study are time-series and may not be stationary. This test aims at testing the null hypothesis that there is a unit root. Following testing procedure (Pfaff, 2008, pp.630), we estimate the ADF equation with the presence of a constant and trend, with an intercept but without trend, and without both constant and trend, respectively. The general equation is expressed as:

$$\Delta P_t = \zeta_1 + \zeta_2 t + \pi P_{t-1} + \sum_{j=1}^{k} \gamma_j \Delta P_{t-j} + u_t \qquad (3)$$

where P is any price time series. If the test for $\pi = 0$ is denied, there is no need to proceed further. If the null hypothesis of H_0: $\xi_2 = \pi = 0$ is rejected, then test again using standardized normal. Under the normal circumstance, if the test for $\pi = 0$ is not rejected, the series is unit root, *I(1)*. Otherwise, it is *I(0)*. If the null hypothesis of H_0: $\xi_2 = \pi = 0$ is not significant, reestimate the equation without a time trend. Likewise, if the null hypothesis of H_0: $\xi_1 = \pi = 0$ is rejected, then test again using standardized normal. Under the normal circumstance, if the test for $\pi = 0$ is not rejected, the series is *I(1)*. Otherwise, it is *I(0)*. If the null hypothesis of H_0: $\xi_1 = \pi = 0$ is not significant, reestimate the equation without a drift or constant and a trend, if it is rejected, it is *I(0)*, otherwise, it is *I(1)*. Alternatively, Phillips-Perron (PP) test is applied to confirm ADF test because the advantage of the PP test is that it allows for weak dependence and heterogeneity of the error process (Phillips and Perron, 1988). Another test is Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test that null hypothesis is a stationary process, where it is unit root process in the former tow tests (Kwiatkowski, et al., 1992). One thing should be kept in mind is that the tests are sensitive to number of lags. The optimum number of lags depends on the likelihood test statistic (Sims, 1980). If three tests can make consistent conclusion on each series as *I(1)*, then a co-integration analysis can be conducted.

Before performing APT test, another requirement needs to conduct co-integration analysis because the analysis is a statistical property of data that can describe the long-term co-movement of economic time series. Engel and Granger propose a two-step estimation procedure to do so. The first step of the procedure is to estimate the long-run relationship between price series as the following:

$$P_{dt} = \varphi_1 + \varphi_2 P_{ut} + \upsilon_t \text{ for } t=1,\ldots,T \tag{4}$$

where υ assigns the error term. Traditional ordinary least squares (OLS) is applied to the equation because the cointegrating vector can be estimated super-consistently (Stock, 1987). In the next step, an augmented Dickey-Fuller test is employed to check the residuals to see if the price series of each equation are cointegrated. The residual of the long-run (LR) relationship is expressed as the following:

$$\Delta\upsilon_t = \rho\upsilon_{t-1} + \omega_t \tag{5}$$

where ω is the error term for the residuals. Given the LR relationship, P_d and P_u are cointegrated if $\rho = 0$ is rejected.

Furthermore, APT tests are conducted by a dynamic ECM-EG with splitting price series and error terms into two parts: positive and negative series in equation (1) if they are cointegrated. Otherwise, error term cannot enter into the equation and we turn to a dynamic asymmetric model in equation (6). If all variables at first difference level and error correction terms are stationary, the OLS method is applied to the ECM-EG models. Note that the model selection with lag lengths is determined by Akaike Information Criterion (AIC) because it is referred to a penalized loglikelihood (Crawley, 2007, pp.353), while the significance of all lags is also considered. The Wald test is applied to examine the APT after the estimation of the model in the equations (1). If the null hypothesis $\beta_3^+ = \beta_3^-$ is rejected, then there is an asymmetric price transmission in the long term. If he null hypothesis $\alpha_2^+ = \alpha_2^-$ or $\beta_2^+ = \beta_2^-$ is denied, then there is an asymmetric price transmission in the short term. Otherwise, there is no symmetric price relationship. Lastly, APT can be further classified as either positive or negative, depending on reaction speed and magnitude (Peltzman, 2000). If downstream price reacts more fully or rapidly to an increase in upstream price than to a decrease, the asymmetry is defined as positive, otherwise, negative correspondingly.

DATA SOURCES

A summary of data description and statistics of the selected variables are reported in Table 1. The data are collected in three stages. In the first stage, standing timber prices are collected from Timber-Mart South (www.tmart-south.com) (1977.1q-2008.4q). In terms of area consistency, the three area prices are converted into two before 1992 because the prices for three reporting areas were changed to two (Prestemon and Pye, 2000). Likewise, the mean in each quarter before 1988 are used as quarterly observation because the reporting frequency has changed from monthly to quarterly since 1988 (Prestemon and Pye, 2000). In order to match timber and lumber prices by region, we average standing timber prices for Southern pine sawtimber over four states (AL, LA, MS, and TX) on the Westside and 11 states (AL, AK, FL, GA, LA, MS, NC, SC, TN, TX, VA) in the South, respectively.

Table 1. *Definition and Data Summary for the Selected Eight Variables*

Variable	*Definition*	*Mean*	*Std. Dev.*	*Min.*	*Max.*
DIW	Lumber dimension of Southern pine 2×4#2 on the Westside in the South	299.5	83.2	177.0	499.0
STW	Lumber stress of Southern pine 2×4#1 on the Westside in the South	332.5	91.0	198.0	535.0
DPW	Average delivered price of Southern pine sawtimber for four western states in the South	291.8	101.7	128.0	485.0
SPW	Average standing price of Southern pine sawtimber for four western states in the South	223.3	83.8	89.0	387.0
BOA	Lumber boards of Southern pine 1×4#3 in the South	235.4	64.1	134.0	408.0
SLE	Lumber selects of Southern pine1×4 in the South	735.6	231.6	342.0	1147.0
ADS	Average delivered price of Southern pine sawtimber for 11 states in the South	273.9	94.2	120.0	439.0
ASS	Average standing price of Southern pine sawtimber for 11 states in the South	201.4	73.1	80.0	274.2

In the second stage, delivered timber prices are also taken from Timber-Mart South. The three area prices are converted in to two for all states and time series are changed from monthly to quarterly like standing timber prices. Correspondingly, delivered timber prices are averaged over four states on the Westside and 11 states in the South, respectively.

In the third stage, the prices of lumber are obtained from the *Forest Product Market Price and Statistics Yearbook* published by Rand Lengths from 1977 to 2008. The prices for lumber dimension of Southern pine 2×4#2 and stress of Southern pine 2×4#1 are used as lumber price series for the Westside in the South. Similarly, the prices for lumber boards of

Southern pine 1×4#3 and selects of Southern pine1×4are employed as lumber price series for the Southern U.S. The mid month observations in each quarter are employed as quarterly data to achieve time consistency because the reporting frequency is on monthly basis. All data are quarterly time series for the period from January 1977 to December 2008 (128 observations). In this study, the price time series are nominal and do not need to be deflated with Producer Price Index because further analysis takes price logarithm form for all variables (Kinnucan and Forker, 1987).

EMPIRICAL RESULTS

The results of the ADF, PP, and KPSS tests are reported in Table 2. It should be noted that all variables are in logarithm form and defined as in Table 1. In addition, all statistics are no longer standard Student t distributed and critical values are larger than the normal (Dickey and Fuller, 1981). Augmented Dickey-Fuller (ADF) test for the null hypothesis that has a unit root against a stationary is used and the 5% and 10% critical values without a constant and trend are -1.95 and -1.62. The ADF test shows that all variables are not significant for the presence of trend and constant. Further estimation without trend and constant at level reveals that all variables are unit root because the null hypothesis cannot be rejected. In contrast, estimation without trend and constant at first difference implies that all variables are not unit root. Lag lengths are determined by Akaike Information Criterion.

*Table 2***.** *Results of the Unit Root Tests*

Series	ADF test		PP test		KPSS test		Results with lags[a]
	Level	First diff.	Level	First diff.	Level	First diff.	
	(no constant & trend)		(with constant & trend)		(with constant)		
DIW	-0.17	-7.00**	-2.90	-11.11**	2.60**	0.10	*I(1)*,2
STW	-0.06	-6.91**	-2.41	-9.96**	2.70**	0.11	*I(1)*,2
DPW	1.32	-5.84**	-1.97	-8.84**	3.79**	0.19	*I(1)*,2
SPW	0.70	-6.87**	-2.00	-9.34**	3.36**	0.19	*I(1)*,2

BOA	-0.41	-4.84**	-3.11	-7.53**	3.32**	0.06	*I(1)*,3
SLE	0.18	-3.91**	-2.07	-6.04**	3.81**	0.26	*I(1)*,2
ADS	1.17	-4.98**	-2.00	-8.55**	3.99**	0.23	*I(1)*,3
ASS	0.92	-6.14**	-1.97	-8.66**	3.66**	0.24	*I(1)*,2

[a] *I(1)* indicates that a variable is nonstationary and integrated of order one.

[b] ** and * denote rejection of the null hypothesis at the 5% and 10% significant levels, respectively.

Similarly, Phillips-Perron (PP) test for the null hypothesis that has a unit root against a stationary is employed and the 5% and 10% critical values incorporating a constant and a linear trend are -3.46 and -3.15. The PP test reveals that all variables are unit root at level including constant and trend, but not integrated of order one at first difference. Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test for the null hypothesis that is stationary is applied and the 5% and 10% critical values including a constant are 0.46 and 0.35. The KPSS test shows opposite results because its null hypothesis is different from the former two tests. The test also suggests that all variables are unit root without trend. Overall, the three tests make a consistent conclusion that all variables are nonstationary and integrated of order one. Thus, Engel-Granger co-integration analysis can be conducted in this study.

The results of Engel-Granger two-step procedure are presented in Table 3. The OLS estimation for long-run relationship reveals that all variables are significant at 5% level or better.

Table 3. ***.*** *Engel-Granger: Co-integration Tests*

Pair of price series	Long run coefficient (t-statistic)	Statistic of ρ for EG co-integration test[a]
DIW-DPW	0.61**(16.17)	-3.74*
STW-DPW	0.62**(17.35)	-3.92**
DPW-SPW	0.90**(57.78)	-2.22

DPW-DIW	1.10^{**}(16.17)	-3.08
DPW-STW	1.14^{**}(17.35)	-3.33
SPW-DPW	1.07^{**}(57.78)	-2.43
BOA-ADS	0.68^{**}(23.29)	-5.73^{**}
SLE-ADS	0.87^{**}(42.78)	-5.29^{**}
ADS-ASS	0.93^{**}(67.36)	-2.91
ADS-BOA	1.20^{**}(23.29)	-5.15^{**}
ADS-SLE	1.07^{**}(42.78)	-4.99^{**}
ASS-ADS	1.05^{**}(67.36)	-3.12

** and * denote rejection of the null hypothesis at the 5% and 10% significant levels, respectively.

The further co-integration analysis indicates that six pairs of price series are cointegrated because the null hypothesis $\rho = 0$ is rejected at 10% significant level or better, while other six pairs are not cointegrated. The six pairs of prices that are cointegrated include two dual relationships between lumber boards of Southern pine 1×4#3 in the South (BOA) and average delivered price of Southern pine sawtimber for 11 states in the South (ADS), and lumber selects of Southern pine1×4 in the South (SLE) and ADS. There are also two one-way relationships from average delivered price of Southern pine sawtimber for four western states in the South (DPW) to lumber dimension of Southern pine 2×4#2 on the Westside in the South (DIW) and from DPW to lumber stress of Southern pine 2×4#1 on the Westside in the South (STW). Note that the critical values are larger than those in the ADF test, given -3.83 and -3.51 for 5% and 10% significant levels (Engle and Yoo, 1987). The six pairs that are cointegrated can be accepted for further ECM-EG analysis. In contrast, the other six pairs of price series that are not cointegrated can be used to conduct vector autoregressive (VAR) analysis at first difference level and produce consistent estimation based on equation (1) because they all are *I(1)*.

The estimated results of the ECM-EG for APT are reported in Tables 4. Again, the model selection with lag lengths is determined by Akaike Information Criterion (AIC).

Table 4. ECM-EG Tests for the Relationships from Upstream to Downstream Price Series

Series	DPW→DIW	DPW→STW	ADS→BOA	ADS→SLE
	Coeff.(*t*-stat.)	Coeff.(*t*-stat.)	Coeff.(*t*-stat.)	Coeff.(*t*-stat.)
ΔP^{+}_{dt-1}	-0.46**(-3.27)	-0.25*(-1.64)	0.07(0.52)	0.34**(2.69)
ΔP^{-}_{dt-1}	-0.25(-1.45)	0.23(1.36)	0.66**(4.26)	0.33**(2.16)
ΔP^{+}_{dt-2}	-	-	-0.25*(-1.91)	-
ΔP^{-}_{dt-2}	-	-	-0.45**(-2.71)	-
ΔP^{+}_{ut}	1.16**(3.76)	0.87**(3.13)	0.25(1.28)	0.13(0.98)
ΔP^{-}_{ut}	0.68**(1.99)	0.46(1.50)	0.92**(3.33)	0.35*(1.92)
ΔP^{+}_{ut-1}	-0.55*(-1.78)	-0.42(-1.54)	-0.08(-0.42)	0.35**(2.84)
ΔP^{-}_{ut-1}	-0.18(-0.51)	-0.12(-0.39)	-0.08(-0.24)	0.01(0.05)
ΔP^{+}_{ut-2}	-	-	0.01(0.05)	-
ΔP^{-}_{ut-2}	-	-	0.57**(2.04)	-
$\Delta \upsilon^{+}_{t-1}$	-0.17(-1.48)	-0.13(-1.16)	-0.20**(-2.53)	-0.23**(-2.55)
$\Delta \upsilon^{-}_{t-1}$	-0.22*(-1.94)	-0.21**(-2.09)	-0.09(-0.90)	-0.13(-1.56)
Wald test short-run	11.0**(ΔP_{dt-1})	3.5(ΔP_{dt-1})	1.2(ΔP_{dt-1})	15.9**(ΔP_{dt-1})
	27.6**(ΔP_{ut})	18.1**(ΔP_{ut})	23.9**(ΔP_{ut})	7.1**(ΔP_{ut})
	4.4(ΔP_{ut-1})	3.3(ΔP_{ut-1})	18.5**(ΔP_{ut-1})	9.3**(ΔP_{ut-1})
Wald tests for long-run	8.3**($\Delta \upsilon_{t-1}$)	7.7**($\Delta \upsilon_{t-1}$)	10.2**($\Delta \upsilon_{t-1}$)	16.2**($\Delta \upsilon_{t-1}$)
APT in LR	Negative	Negative	Positive	Positive

** and * denote rejection of the null hypothesis at the 5% and 10% significant levels, respectively.

The analysis reveals that the error-correction terms for four pairs of price series are negative and significant at the 5% level or better. This further confirms the finding of the long term relationship by the short-term model. The negative coefficients of the error-correction terms guarantee that the long term equilibrium can be achieved. The absolute value of the error-correction terms implies the adjust speed to the long-term equilibrium. The results show that the adjustment for all equations is slow. In this study, the critical values of Wald-test for asymmetry at the 5% and 10% significant levels are 5.99 and 4.61, respectively. The Wald tests indicate that the asymmetric price transmission applies to the four pairs of price series (DPW→DIW, DPW→STW, ADS→BOA, and ADS→SLE) in the long term and the short term. According to the speed and magnitude of the long run adjustment, the results imply that the positive APT exists in two pairs of price series (ADS→BOA and ADS→SLE), while the other two pairs of price series (DPW→DIW and DPW→STW) have the negative APT phenomenon in the long term. In the short term, there is no consistent conclusion on the classification of APT.

DISCUSSION AND CONCLUSION

In this study, the existence of asymmetry in the price transmission in the timber and lumber markets in the Southern United States is examined by time series method vertically. The data feature is examined by the ADF, PP, and KPSS tests because it will produce spurious regression with traditional method if price time series occur nonstationary. In addition, EG co-integration analysis is conducted to see if they can achieve long term economic equilibrium. The further APT analysis with ECM is used to examine the existence of asymmetry in the price transmission in the short and long term. The advantage of the method is that it picks up the dynamic characteristics of time series of data.

The results of the ADF, PP, and KPSS tests reveal that all variables are nonstationary and integrated of order one. This is in line with the literature (Zhou and Buongiorno, 2005). Thus, traditional way that deals with the nonstationary data using variables at level will produce spurious estimation. On the other hand, an unrestricted VAR system in first difference form cannot be used either if all variables are nonstationary and cointegrated, because the estimates obtained by the standard VAR model cannot be consistently specified (Engel and Granger, 1987).

The results of Engel-Granger two-step procedure indicate that four pairs of price series are cointegrated. The results are not consistent in the literature (Zhou and Buongiorno, 2005). The possible explanation is that this study breaks market linkages down into two stages, while the previous studies just have one stage. In addition, the previous study uses national lumber price index as a downstream price that does not match stand timber price well regionally. The presence of the co-integration for the four pairs of price series allows the construction of ECM-EG model. The estimated results of the ECM-EG for APT reveal that the asymmetric price transmission exists in the four pairs of price series in the long term and short term. After a careful examination, we find the positive APT for two pairs of price series in the long term. The existence of positive APT is widely found in the literature. This finding indicates that any price movement that squeezes the margin is transmitted more rapidly and /or completely than the movement that stretches the margin (Meyer and Cramon-Taubadel, 2004). Meanwhile, the negative APT for the other two pairs of price series is found in the long term. The negative APT is not usually observed in the past but does exist in the forest sector in the case of Greece (Koutroumanidis, Zafeiriou and Arabatzis, 2009), agricultural sector or other sectors (Peltzman, 2000; Meyer and Cramon-Taubadel, 2004). This finding implies that a shock that may lead to an increase in the cost of lumber production causes an increase in the lumber price but not in a symmetric way. The proposed explanation for the presence of vertical APT in the forest sector in the Southern United States is due to non-competitive markets and adjustment costs. Political intervention, asymmetric information, and inventory adjustment can also be candidates for the explanation for the presence of vertical APT.

Therefore, it should be kept in mind that the results from this study need to be interpreted with caution. The findings are based on relatively less types of timber markets. In addition, the findings are constrained by the empirical analysis technology. Nevertheless, this study is helpful to understand not only the gaps in economic theory but also the existence of market failure, and thus possible welfare distortion. The results should be interesting to those who are interested in market analysis and policy assessment. Further research is needed to examine if there exists APT in paper markets and spatial APT considering the large variations in the U.S. Moreover, the causes of APT should be investigated and more complicated methods such as threshold co-integration analysis should be applied.

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