Timber Harvesting Margins in the Southern United States: A Temporal and Spatial Analysis

Changyou Sun and Daowei Zhang

Abstract: This study focuses on the logging sector by analyzing timber harvesting margins in the southern United States between 1977 and 2001. The real growth rate of harvesting margins has been negative for pine pulpwood, while positive for pine sawtimber, hardwood pulpwood, and hardwood sawtimber. Harvesting margins for pulpwood are more stable over time and more integrated spatially when compared with those for sawtimber. There is no perfect integration in the logging sector by timber product and no individual state is found to lead the logging service market. The revealed patterns are explained in terms of changing demand for forest products and forest industry structure. FOR. SCI. 52(3):273–280.

Key Words: Cointegration, forest industry, landowner, logging.

IN 1997, THE SOUTHERN UNITED STATES accounted for approximately 64% of timber harvesting in the country and some 71% of timberland in the South was owned by nonindustrial private forest landowners (Smith et al. 2001). The linkage between nonindustrial landowners who usually sell timber on the stump and industrial firms who need logs at their mills is the logging sector [1], which consists of independent loggers (contractors) and wood dealers. Independent loggers are entrepreneurs who have a logging crew, purchase timber from nonindustrial landowners, harvest timber, and sell delivered logs to industrial mills. Independent loggers also harvest timber owned or controlled by industrial firms or wood dealers under contract. Wood dealers are firms that have a standing timber supply agreement with industrial firms, from whom they take orders and perform wood procurement and timber harvesting. Wood dealers are usually independent from forest industry as well.

The logging sector has been important to the southern economy, not only in providing raw materials for the wood-based forest industry, but also through its own employment and income creation. In 1997, the value of shipments in the logging sector in the United States reached \$14 billion (Table 1), which became part of a much larger industry including wood product manufacturing (\$89 billion), paper manufacturing (\$150 billion), and furniture manufacturing (\$64 billion). In 1997, the logging sector employed 83,212 people, roughly equal to that in 1977.

The logging sector has been characterized by low barriers to entry in terms of capital intensity and skilled labor requirements, relatively unsophisticated technology, and a large number of logging firms. In 1997 there were 13,461 logging firms nationwide and on average each firm had only 6.2 employees. Surveys from individual states revealed a similar pattern. For example, in Georgia an average logging firm had capital investments of \$613,000 in 1997, had 9.8 employees, and produced 552 cords of wood weekly. The total number of logging firms in Georgia was well over 1,000 in 1997 (Greene et al. 2001).

The logging sector is in the middle of the supply chain of timber: forest landowners, logging firms (loggers), and forest industrial firms (processors). Processors pay the delivered price (P_d) for timber, which consists of logging service fees or harvesting margins (HM) to loggers and stumpage price (P_f) to forest landowners (HM $= P_d - P_f$). Logs are bulky in nature, resulting in high transportation costs. Studies have been conducted to examine the evolution, structure, and integration of forest industry and stumpage markets (e.g., Murray 1995a, b, Yin et al. 2002, Murray and Prestemon 2003). The forest industry, especially the paper industry, has been characterized as monopsonistic or oligopsonistic in the United States (Murray 1995a, b), Sweden (Brännlund et al. 1985), Finland (Kallio 2001), and Canada (Bernstein 1992).

Studies about the logging sector have been done on logging firm profiles, cost structure, and technical efficiency (e.g., Carter et al. 1994, Cubbage and Carter 1994, Luppold et al. 1998, Greene et al. 2001), often with limited geographical or time coverage. In this study, we focus on the logging sector across the southern states and over past 25 years. This is done by examining timber harvesting margins, defined as delivered log prices minus stumpage prices paid to landowners. In particular, ordinary least square regression and coefficient of variations are used to examine the temporal variations of harvesting margins by timber product, and cointegration analyses are used to evaluate the integration of the logging service markets across states. Spatial market linkages have been studied in the literature under the notion of the law of one price (Ardeni 1989), market efficiency (Washburn and Binkley 1990), or

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Table 1. **Selected statistics for logging and forest manufacturing industries in 1997**

NAICS code	Description	Number of companies	Number of employees	Value of shipments ($\$10^6$)
1133	Logging	13,461	83,212	13,626
321	Wood product mfg.	15,621	570,034	88,470
322	Paper mfg.	3,808	574,274	150,296
327	Furniture & related mfg.	19,838	603,668	64,299

Source: US Department of Commerce (2001b).
Note: Logging has been separated from wood product manufacturing (mfg.) in the statistics since the North American Industry Classification System (NAICS) was adopted in 1997. The number of companies is only reported in census years and 1997 is the most recent one with data available.

market integration (Sanjuan and Gil 2001). Cointegration analysis has been used extensively in spatial aspects of the forest economics literature (Jung and Doroodian 1994, Alavalapati et al. 1997, Murray and Wear 1998, Yin et al. 2002).

The next two sections describe the methodologies and data used in this study, followed by empirical results and conclusions. The revealed patterns are explained in terms of changing demand for forest products and forest industry structure. The results of this study may improve our understanding of the economic welfare of loggers and the integration of the logging sector.

Methodology

Temporal Changes in Harvesting Margins

Temporal changes in harvesting margins can be revealed by comparing the means and coefficients of variation (CV) of nominal harvesting margins. Comparisons can be done among states and among timber products. Harvesting margins with smaller CVs are more stable, which could mean less volatile income stream for loggers.

Changes of harvesting margins over time also can be exposed by assessing the real growth rate of harvesting margins, which can be calculated from the regression

$$\ln \text{RHM} = a + bT + \varepsilon_t, \tag{1}$$

where ε_t is the error term and T is time. RHM is the real harvesting margins (nominal harvesting margins are deflated to reveal the real growth rate). The coefficient b can be interpreted as the real growth rate given the semi-logarithm specification. Because this study uses quarterly data, the quarterly growth rate can be annualized by multiplying the coefficients b by four.

Spatial Price Linkages

Spatial price linkages or spatial integration generally refers to a measure of degree rather than a specific relationship. Regions may be more or less integrated. At one extreme are completely separated markets and at the other are perfectly integrated markets. Earlier studies examining the relationship between prices have looked at correlation coefficients or have used the following type of regression (Goodwin and Schroeder 1991):

$$P_{1t} = \gamma_0 + \gamma_1 P_{2t} + \mu_t, \tag{2}$$

where P_{1t} and P_{2t} denote prices from two regions under consideration, γ_0 and γ_1 are parameters to be estimated, and μ_t is an error term. The hypothesis of perfect market integration is tested by examining whether the slope equals unity and the intercept equals zero.

Because the data used in this study are time-series data, they may change over time and not be stationary. The presence of nonstationarity could invalidate the standard econometric tests, such as those for Equation 2, and give misleading results regarding the degree to which price signals are being transmitted between markets. The stationarity property of individual time series may be examined by the Augmented Dickey-Fuller (ADF) test (Enders 1995). If the price series are nonstationary, dynamic time series techniques such as cointegration analysis should be used in evaluating spatial price linkages.

This study adopts the Johansen multivariate cointegration method [2] (Johansen 1988, 1991, Johansen and Juselius 1990). It starts with a vector autoregressive model. Consider a vector X_t with N nonstationary variables of interest, defined by a general polynomial distributed lag process given as

$$X_t = \pi_1 X_{t-1} + \cdots + \pi_k X_{t-k} + \varepsilon_t, \tag{3}$$

where $t = 1, \ldots, k$ and ε_t is a vector of error terms. It can be reformulated into a vector error correction model as

$$\Delta X_t = \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \Pi X_{t-k} + \varepsilon_t, \tag{4}$$

where

$$\Gamma_i = -\left(I - \sum_{i=1}^{k-1} \pi_i\right), \quad \Pi = -\left(I - \sum_{i=1}^{k} \pi_i\right),$$

and I is an $N \times N$ identity matrix. The above model contains information on both the short-run and long-run adjustments to changes in X_t via the estimates of $\hat{\Gamma}_i$ and $\hat{\Pi}$, respectively. The number of distinct cointegrating vectors that exist among the variables of X_t, r, is given by the rank of Π. Π is an $N \times N$ matrix, and is also defined as two $N \times r$ matrices, α and β, such that

$$\Pi = \alpha\beta' \tag{5}$$

where α represents the speed of adjustment to disequilibrium, and β is a matrix of long-run coefficients. The existence of cointegrating relationships indicates that, although X_t is nonstationary, the linear combinations of $\beta' X_t$ are indeed stationary, and hence the columns of β form r distinct cointegrating vectors.

Two types of tests, the trace statistic and maximum Eigenvalue statistic, are used to detect the number of cointegrating vectors, r, which is an indictor of the extent of integration among variables. The difference between the number of variables N and the cointegrating vectors r, i.e., $N - r = S$, represents the number of common integrating factors in the market. A smaller S value suggests a more integrated market. When S is equal to one, it indicates that the market is highly integrated and the pair-wise price transmission is proportional.

With the results of the cointegration analysis, two economic questions about the logging sector can be answered by further tests. One question is whether the logging service market for each timber product is perfectly integrated across the southern states. This can be examined by imposing restrictions on the cointegrating vectors and carrying out a multivariate test of the law of one price. In a set of N markets, two conditions should be satisfied for perfect integration: every pair of prices must be cointegrated, hence $r = N - 1$; and every pair of prices must fulfill the parity condition (Goodwin and Schroeder 1991, Sanjuan and Gil 2001, EViews 2004). Thus, the hypothesis is formulated as H_0: there exists perfect integration among the N variables. The restrictions imposed are

$$\beta'_{r\times(N+1)} = \begin{array}{c} \begin{bmatrix} 1 & -1 & 0 & \dots & 0 & * \\ 1 & 0 & -1 & \dots & 0 & * \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & 0 & 0 & \dots & -1 & * \end{bmatrix} \end{array} \begin{array}{c} 1 \\ 2 \\ \vdots \\ r = N-1 \end{array} \tag{6}$$

where each row represents a cointegration vector and the asterisks indicate that the corresponding parameter enters without restriction. The last column represents the constant term in each cointegration vector. This hypothesis satisfies the identification conditions in Johansen and Juselius (1994) and imposes one over-identifying restriction on each vector.

Another question is whether there are some leading or driving prices in the long-run joint evolution of the system. This can be examined by testing the weak exogeneity of each price (Sanjuan and Gil 2001). A weakly exogenous variable is a driving variable in the model, which pushes the model away from adjusting the long-run equilibrium errors, but is not pushed by the other variables in the model. Thus, it may be interpreted as playing a dominant and leading role in the price formation. The null hypothesis of weak exogeneity of an individual price X_i is tested by setting a zero row in α, i.e., H_0: $\alpha_{ij} = 0, j = 1, \dots, r$. Rejection of the null hypothesis implies that the price considered does not play a leading role. If none of the prices considered plays a leading role, then there is no price leader.

Data

The harvesting margins for four timber products (hardwood pulpwood, mixed hardwood sawtimber, pine pulpwood, and pine sawtimber) in 11 southern states are covered in this study. The states are Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia. All data are quarterly and from Timber Mart-South (TMS; Norris 1977–2001). The time period covers 25 years from 1977 to 2001. In all, the data set has 44 price series of harvesting margins for these states, and each series has 100 observations.

The harvesting margins are computed as the price spreads between the delivered prices and stumpage prices on the basis of state averages. Although TMS also reports regional prices within each state, the spatial aggregation of regions within a state was changed from three to two regions in 1992, making consistent regional comparisons difficult. We assume that the harvesting margins for each timber product in different regions in a state are integrated to the same degree, so state averages represent the logging service market well.

Nominal harvesting margins are used for computing means and CVs, and for cointegration analysis. Real harvesting margins are used in calculating real growth rates. The deflator is the Producer Price Index for all commodities from the US Department of Commerce (1982–84 = 100). As an example, Figure 1 shows the nominal and real harvesting margin for pine pulpwood in Georgia over the past 25 years. The nominal harvesting margin has been volatile, but generally increasing. The real harvesting margin is less volatile. The real harvesting margin kinked in the case of pine pulpwood in Georgia because of the high inflation rate around 1980 [3]. Graphs for other series have similar patterns.

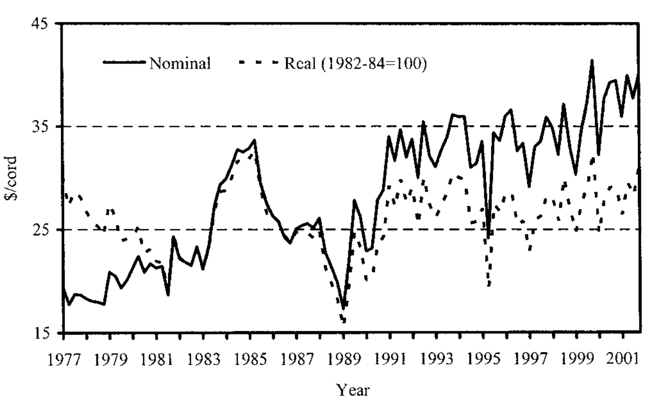

Figure 1. Nominal and real harvesting margin of pine pulpwood in Georgia.

Empirical Results and Interpretation

Temporal Changes of Harvesting Margins

Table 2 presents the CVs and means of the harvesting margins for each timber product by state. The changing patterns are more noticeable by timber product than by state. First, by timber product, the average CV is 0.23 for hardwood pulpwood, 0.18 for pine pulpwood, 0.32 for mixed hardwood sawtimber, 0.42 for pine sawtimber. So the harvesting margins are more volatile for sawtimber than for pulpwood, and pine sawtimber is most volatile. Note that the average of harvest margins for pulpwood is larger than that for sawtimber: 19% in hardwood and 40% in pine, based on the conversion ratio of 3.02 from Cord to MBF (Doyle in hardwood) and 2.80 from Cord to MBF (Scribner in pine). This may be due to the economy of size in harvesting and transporting sawtimber. Second, by state, Mississippi and North Carolina show smaller CVs for most timber products than other states. Finally, a paired *t*-test is conducted to compare the averages between individual timber products for each state. Within each state, the averages for the four timber products are statistically different, at the 10% level for pine pulpwood and hardwood pulpwood, and 5% for other pairs. Across states, the averages are compared by timber product, and whether the averages are the same depends on the state and timber products compared.

To find out whether the increasing patterns of nominal harvesting margins are also true in real terms, annualized real growth rates are calculated using real harvesting margins, and the results are reported in Table 3. Overall, for most states, the real growth rate is negative for pine pulpwood but positive for the other three timber products. Two states, Mississippi and North Carolina, show some different patterns.

Specifically, for hardwood pulpwood, 10 of 11 regressions have significant positive growth rates. The average of the real growth rates is 0.53% per year. For mixed hardwood sawtimber, all states except North Carolina and Mississippi have positive growth rates. The average for all states is 0.75%, and without the two negative growth rates, 1.22%. Pine sawtimber has similar patterns to mixed hardwood sawtimber, and its average for all states is 1.44%, and without the two negative growth rates, 2.02%. Pine pulpwood has a totally different pattern. For the 11 states, nine have negative growth rates and seven of them are significant at the 5% level or better. Only one state (Georgia) has positive growth rate. The average for all states is −0.44%, and for nine states with negative rates, −0.61%. Thus, pulpwood has a smaller growth rate than sawtimber, and pine pulpwood has negative growth rate for most states. North Carolina and Mississippi have different patterns, especially for mixed hardwood sawtimber.

The above temporal changes of the harvesting margins may be related to several factors. Industry growth and increasing demand for timber in the South may explain the overall increasing trend for most of the timber products. For example, there has been substantial shift of consumption from pine pulpwood to hardwood pulpwood in recent decades, even though pine pulpwood production still dominates in the South. Hardwood pulpwood demand has doubled in the last 20 years, in contrast to a small increase in softwood pulpwood production. That leads to a higher stumpage price (Zhang and Bliss 1998) and may contribute to the increasing harvesting margins for hardwood pulpwood. As an exception, demand for pine pulpwood in Georgia, which is ranked first in terms of value of shipment in paper products (US Department of Commerce 2001a), may also result in the abnormally increasing harvesting margins for pine pulpwood in Georgia. Other factors, such as longer hauling distance and small tree sizes, may also contribute to the increasing trend for most timber products. Different state attributes related to the logging services (e.g., worker compensation insurance, truck weight regulations,

Table 2. Means and coefficients of variation of timber harvesting margins

State	Hardwood pulpwood		Mixed hardwood sawtimber		Pine pulpwood		Pine Sawtimber	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV
Alabama	32.25	0.22	91.15	0.29	31.27	0.18	68.67	0.41
Arkansas	35.07	0.23	86.33	0.33	34.42	0.18	65.33	0.53
Florida	34.41	0.24	91.52	0.40	26.23	0.24	72.29	0.50
Georgia	32.21	0.21	88.89	0.35	28.37	0.23	61.87	0.36
Louisiana	37.37	0.24	90.47	0.30	35.24	0.19	57.35	0.42
Mississippi	34.59	0.21	75.31	0.26	32.81	0.15	48.55	0.30
N. Carolina	34.58	0.21	87.19	0.28	33.53	0.11	62.34	0.39
S. Carolina	32.45	0.21	87.47	0.32	31.80	0.19	62.49	0.38
Tennessee	33.38	0.22	77.47	0.38	31.16	0.15	61.16	0.34
Texas	35.90	0.21	91.63	0.35	34.35	0.18	68.29	0.58
Virginia	34.64	0.32	91.00	0.25	33.53	0.21	76.65	0.40
Average	34.26	0.23	87.13	0.32	32.06	0.18	64.09	0.42
Mean ratio	1.19				1.40			

Note: (1) For both hardwood pulpwood and pine pulpwood, the unit is \$/standard cord; for mixed hardwood sawtimber, it is \$/thousand board feet (MBF, Doyle); and for pine sawtimber, it is \$/thousand board feet (MBF, Scribner). (2) "Average" is the average value of mean or CV of all the 11 states. (3) For "Mean ratio," 1.19 is the ratio of hardwood pulpwood's mean over hardwood sawtimber's (34.26 × 3.02/87.13); 1.40 is similarly calculated for softwood. Note the units are different and the conversion ratios are 3.02 from cord to MBF (Doyle in hardwood) and 2.80 from cord to MBF (Scribner in pine). The average of harvest margins for pulpwood is larger than that for sawtimber—19% in hardwood and 40% in pine.

Table 3. Annualized real growth rates of timber harvesting margins (%)

State	Hardwood pulpwood	Mixed hardwood sawtimber	Pine pulpwood	Pine sawtimber
Alabama	0.31*	1.08[a]	−0.51[a]	2.30[a]
Arkansas	0.52[a]	1.21[a]	−0.41[b]	3.53[a]
Florida	0.69[a]	1.86[a]	−0.03	2.02[a]
Georgia	0.27*	1.00[a]	0.48[a]	1.71[a]
Louisiana	0.47[a]	1.03[a]	−0.52[a]	0.88[b]
Mississippi	0.12	−1.49[a]	−1.44[a]	−2.05[a]
N. Carolina	0.50[a]	−1.22[a]	−1.42[a]	0.96[b]
S. Carolina	0.40[a]	1.67[a]	−0.07	2.08[a]
Tennessee	0.46[a]	1.31[a]	−0.74[a]	−0.27
Texas	0.28[b]	1.72[a]	−0.37[a]	3.58[a]
Virginia	1.75[a]	0.10	0.24	1.07[a]
Average	0.53	0.75	−0.44	1.44
		1.22	−0.61	2.02

*Significant at the 10% level; [a] Significant at the 1% level; [b] Significant at the 5% level.
Note: (1) The real growth rates from the regression are quarterly and are annualized by multiplying by 4; (2) For mixed hardwood sawtimber, the average value in the last row excludes the two negative values; for pine pulpwood, it excludes the two positive values; for pine sawtimber, it excludes the two negative values.

and fuel prices) may also have contributed to the variations of harvesting margin changes across states.

Nevertheless, these factors alone still can not fully explain why the changes of harvesting margins vary significantly by timber product, or more specifically, why the harvesting margin for pine pulpwood has been decreasing for most southern states. Changes in the forest industry structure and input substitution may explain some of the remaining differences. The paper industry has become more concentrated than the wood products industry in the past decades. That may give paper mills some market power in bargaining with loggers for a lower price for delivered wood. Furthermore, there have been extended periods in the past decades when the market for the wood products industry was strong, but that for the paper industry was weak. Wood products mills produce large quantities of residue chips, and paper mills take these residues first and roundwood second. Market power and input substitution could thus put a downward pressure on the harvesting margins for pine pulpwood, which is the major fiber source for paper mills [4].

Similarly, because the southern wood furniture industry is highly concentrated in North Carolina and Mississippi, which ranked No. 1 and No. 2 in terms of value of wood furniture shipment in 1997 (US Department of Commerce 2001a), harvesting margins for hardwood sawtimber in these two states are declining, in contrast to an increase in all other states. However, decline in harvesting margin for pine sawtimber in Mississippi remains unexplained.

Spatial Price Linkages

A prerequisite for cointegration analysis is that individual variables should be integrated on the same order, thus the stationarity property of individual harvesting margins needs to be examined. The ADF test was used and the length for the test was determined by the Akaike information criterion (AIC) criterion. The results reveal that all the harvesting margins are nonstationary and integrated of order one [5]. Consequently, cointegration analysis was conducted.

Implementation of the cointegration analysis also requires the determination of a lag length for the model. Five criteria have been used in the process. They are the sequential modified LR test statistic, final prediction error (FPE), AIC, Schwarz information criterion (SIC), and Hannan-Quinn information criterion (HQ) (EViews, 2004). For hardwood pulpwood, all criteria conclude that the lag length is six at the 5% level. For the other three timber products, all criteria except SIC conclude that lag length is six, and SIC suggests that lag length is two. Lag lengths were set to six for all timber products.

Johansen's multivariate cointegration analyses were conducted for each of the four logging service markets by timber product, and each model has 11 harvesting margins from the individual states. The results of the cointegration tests are presented in Table 4. For both hardwood pulpwood and pine pulpwood, trace and maximum Eigenvalue statistics revealed that the number of cointegrating vectors is 10. It is 9 for mixed hardwood sawtimber and 8 for pine sawtimber. Therefore, the degree of integration is high for each of the four logging service markets by timber product in the South. The logging sector for both hardwood pulpwood and pine pulpwood are more integrated regionally than that for sawtimber. The logging sector for pine sawtimber is the least integrated [6].

The statistical adequacy of the models was examined using several misspecification tests. The multivariate LM tests for first-order residual autocorrelation are not significant. The null hypothesis of heteroskedasticity is rejected for all models. In addition, the long-run exclusion tests are conducted for each harvesting margin in each model. The null hypothesis is that an individual harvesting margin can be excluded from the cointegrating space. It is tested by setting a zero row in β, i.e., H_0: $\beta_{ij} = 0, j = 1, \ldots, r$. The null hypotheses are rejected in all cases. Therefore none of these variables can be excluded from the cointegration

Table 4. Cointegration test

H_0	Hardwood pulpwood		Mixed hardwood sawtimber		Pine pulpwood		Pine sawtimber	
	Trace	Max	Trace	Max	Trace	Max	Trace	Max
$r = 0$	1625.1[a]	456.2[a]	920.5[a]	249.8[a]	1567.6[a]	427.1[a]	1034.5[a]	319.9[a]
$r = 1$	1168.9[a]	300.3[a]	670.7[a]	206.3[a]	1140.5[a]	272.8[a]	714.6[a]	193.3[a]
$r = 2$	868.6[a]	253.0[a]	464.3[a]	129.4[a]	867.7[a]	226.6[a]	521.3[a]	142.0[a]
$r = 3$	615.6[a]	196.9[a]	335.0[a]	102.8[a]	641.1[a]	212.2[a]	379.3[a]	117.9[a]
$r = 4$	418.7[a]	111.9[a]	232.2[a]	61.5[a]	428.9[a]	157.9[a]	261.4[a]	108.9[a]
$r = 5$	306.8[a]	93.4[a]	170.7[a]	54.1[a]	271.0[a]	88.6[a]	152.5[a]	53.4[a]
$r = 6$	213.4[a]	91.4[a]	116.5[a]	42.6[a]	182.4[a]	79.8[a]	99.2[a]	39.4[a]
$r = 7$	121.9[a]	53.0[a]	74.0[a]	34.7[a]	102.5[a]	46.9[a]	59.7[a]	31.4[b]
$r = 8$	68.9[a]	40.2[a]	39.2[a]	25.5[a]	55.7[a]	33.6[a]	28.3	18.5
$r = 9$	28.7[a]	28.6[a]	13.7	9.7	22.1[a]	19.2[a]	9.9	7.3
$r = 10$	0.1	0.1	4.0[b]	4.0[b]	2.9	2.9	2.6	2.6
r	10	10	9	9	10	10	8	8

[a] Significant at the 1% level; [b] significant at the 5% level.

space, and each variable has a long-run relationship with other variables in the system.

The test for perfect integration of the logging sector was conducted for hardwood pulpwood and pine pulpwood because only these two timber products have 10 cointegrating vectors and meet $r = N - 1$. The statistics for mixed hardwood pulpwood is 305.5, for pine pulpwood it is 291.9 with the distribution of $\chi^2(10)$. The null hypotheses are rejected for both timber products. Therefore, for both the mixed hardwood pulpwood and pine pulpwood, there is no perfect integration in the sense that changes in prices are not perfectly transmitted, even though the logging service market is highly integrated. These results suggest that arbitrage of logging services over a long distance is difficult and unlikely to happen in the South.

Finally, weak exogeneity for each price was investigated using tests on the significance of parameters in matrix α. The statistics have a chi-square distribution and the number of cointegration vectors in the model as the degree of freedom (Table 5). The null hypotheses are rejected for all harvesting margins. Therefore, no leading or driving prices (i.e., states) exist in the examined logging service markets.

Conclusions

This study is an initial attempt to assess the logging sector and the variations of harvesting margins over time and across states in the South. Using regression and cointegration analyses, we examine the harvesting margins of four major timber products in 11 southern states between 1977 and 2001. Our results show that (1) the real growth rate of the harvesting margin is negative for pine pulpwood and positive for three other timber products; (2) harvesting margins for both hardwood and softwood pulpwood are more stable over time and more integrated spatially in comparison to those for sawtimber; (3) harvesting margins for pine sawtimber are the most volatile within a state and are the least integrated among states compared to other timber products; and (4) the logging sector is highly integrated by individual timber product but there is no perfect integration and no individual state is found to lead the logging service market.

These findings are a contribution to the literature on the logging sector and may motivate more future studies. First, the economic welfare of loggers should be incorporated into policy analysis, such as timber harvesting regulations and

Table 5. Likelihood ratio tests of weak exogeneity

State	Hardwood pulpwood	Mixed hardwood sawtimber	Pine pulpwood	Pine sawtimber
Alabama	85.12	56.62	28.77	26.86
Arkansas	93.00	67.65	63.70	61.02
Florida	198.71	82.33	113.36	45.99
Georgia	74.62	47.41	118.79	83.23
Louisiana	92.50	34.93	114.65	59.48
Mississippi	56.04	46.75	46.84	31.48
N. Carolina	45.07	72.95	99.00	47.39
S. Carolina	101.55	39.76	179.86	76.13
Tennessee	87.65	32.81	142.56	47.17
Texas	93.47	62.67	55.11	31.93
Virginia	94.75	32.70	69.22	43.32

Note: The likelihood ratio tests have a χ^2 distribution and the degree of freedom is equal to the number of cointegrating vectors. All above statistics are significant at the 1% level and the null hypotheses of weak exogeneity are rejected.

tariffs on Canadian lumber. Previous studies generally only consider industrial firms and forest landowners. But when a new environmental regulation is imposed on the forest industry, loggers may share the cost along with processors and landowners. However, if demand for forest products increases and results in higher prices, it is less clear if loggers will benefit notably, given that the competition in the logging sector has been intense. Future research is needed for the welfare distribution among these players due to either supply or demand change in the three markets (i.e., stumpage, delivered logs, and forest products). This calls for a vertically integrated model that consists of landowners, loggers, and forest products manufacturers. Second, harvesting margins presented in this article could be linked to the increase or decline of the logging sector, such as number of logging firms, average production level, and profitability. Finally, independent loggers and wood dealers could be studied comparatively in terms of their number and financial performance over time.

Endnotes

[1] Forest industry in this study refers to the manufacturing of forest products using various timber/logs as raw materials and includes the paper industry, the wood products industry, and the wood furniture industry. The logging sector covers logging firms and wood dealers that provide logging services.

[2] The other methodology in cointegration analysis is the Engle-Granger method, a bivariate approach (Enders 1995). The method is limited by the fact that cointegration considerations are confined to pair-wise comparisons and it requires one of the two prices to be designated as exogenous. In this study, multiple price series are involved so the method is inappropriate.

[3] To detect any possible effect of high inflation, analyses have been done for data from 1981 to 2001. All results remain the same qualitatively.

[4] In 2002, the source of pulpwood in the South was softwood roundwood (45%), softwood residues (24%, mainly a byproduct of sawmills), hardwood roundwood (21%), and hardwood residues (10%, Johnson and Steppleton 2004).

[5] The test results for the 44 harvesting margins are available by request from the authors.

[6] There is no statistical test for comparison of market integrations between two commodities. So the difference between the cointegrating vectors of 10 for hardwood pulpwood and 9 for hardwood sawtimber is uncertain. However, because the four individual models are very similar—they have the same geographical coverage, time period, and data sources—it is reasonable to draw these conclusions based on the number of cointegrating vectors.

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