Roundwood Market Integration in Finland: A Multivariate Cointegration Analysis

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Abstract

Roundwood market integration in Finland is analysed by four wood assortments and four regions both in the short- and long-run. Using Johansen's multivariate cointegration tests and monthly stumpage prices for 1985–96, tests indicated full long-run market integration only in the case of pine sawlogs. Causation between regional wood prices mainly originated in the largest wood-using regions of eastern Finland with respect to pine sawlogs and spruce pulpwood, and from the southern Finland with respect to pine and spruce pulpwood markets. Results from the dynamic error-correction models indicate significant departures from the conditions for short-run market integration. The structural break in the market environment caused by the end of central price recommendations was found to have no significant effect on the short-run models.

Keywords: Cointegration, law of one price, market integration, regional prices, short-run dynamics, stumpage market.

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Introduction

There are strong export demand-driven price and quantity fluctuations in the Finnish roundwood market. The market is characterized by 300 000 non-industrial private forest owners (NIPFs) who own altogether 62 per cent of forest land and produce approximately 80 per cent of the commercial roundwood (Kuuluvainen & Ovaskainen, 1994). In contrast, mergers between forest industry companies have highly concentrated buyer structure in the roundwood market during the last decade. Today, the three largest companies account for 80 per cent of traded roundwood (Uusivuori & Mykkänen, 1996).

The issue of market integration has implications for modelling timber markets: if markets are not spatially well integrated, the cross-sectional aggregation of demand and

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supply loses its foundation. Previous econometric studies on the Finnish wood market have assumed a national market for sawlogs and pulpwood (e.g. Kuuluvainen *et al.,* 1988; Hetemäki & Kuuluvainen, 1992; Toppinen & Kuuluvainen, 1997). This assumption is at least partly justified by the existence of a voluntary stumpage price recommendation system involving central associations of forest industry and private forest owners during the 1980s.[1] However, the existence of national stumpage market in Finland has been only an assumption and it has not been previously tested.

To fill this gap, this paper focuses on testing the extent of market integration among four regional stumpage markets in Finland during 1985–96. First, the null hypothesis of the law of one price between regional stumpage prices in Finland is tested by means of the multivariate cointegration method developed by Johansen (1988, 1995). Second, regional price interrelationships are analysed to test the hypothesis that price changes in the largest wood-using regions, i.e. eastern and southern Finland, affect prices on the rest of the market. Motivation for this division is given by interregional differences in timber species. Most importantly, there is very little spruce growing in the northern part of Finland and there is an uneven geographic distribution of forest industry, firms being more heavily concentrated in the east and south.[2]

Third, we test whether the collapse of the stumpage price negotiation system effected the integration of Finn-

[1] Comprehensive nationwide stumpage price agreements between associations of forest industry and forest owners existed between the felling seasons 1978/79 and 1990/91 in Finland. Recommendations concerned prices for an average stand, tree size, haulage distance and density per hectare. This negotiation system collapsed in 1991 and was inoperative for a period of three associayears. In 1994 a new contract was negotiated following guidelines from the Finnish Office of Free Competition. In 1995, price negotiations were additionally decentralised by the division of Finland into four different price regions. The new agreements prohibited import or export barriers, and in general, became more flexible. Gradually the system evolved even further. Currently, it is concerned only with discussions of the price expectations of individual firms and forest owners. Despite the different form of agreements, it is important to note that a negotiation between an individual forest owner and a wood buyer has been important for determining actual prices in the Finnish roundwood market, transaction by transaction.

[2] Directions of roundwood trade flows are discussed in more detail in Västilä & Peltola (1997).

ish wood markets. For this last test, the cointegration analysis is presented in two sub-samples of data, one from during and one from after the application of nationwide price recommendation system. Possible effects of this structural break on the dynamics of regional prices are further modelled using structural error-correction models. The analysis of market adjustment mechanisms also provide a test for roundwood market integration as a more restrictive short-run relationship. Additionally, it gives indication of the suitability of the cointegration method for analysing the integration of the markets considered.

Moreover, unlike in previous studies of Finland, we have disaggregated the market by wood species into spruce and pine as well as by product types into sawlogs and pulpwood, since it can be assumed that prices for different roundwood types may contain information that would be lost in the aggregation of data. By doing this we hope to gain new information on possible behavioural differences that may exist between different wood assortments in the Finnish roundwood market.

THE CONCEPT OF MARKET INTEGRATION

According to Ravallion (1986), measures of market integration can be viewed as basic data for understanding how specific markets work and provide valuable information on the dynamics of market adjustment. The physical movement of goods from one place to another is a potential source of information on the geographic extent of a market.[3] However, no volume of physical trade alone will ensure that two areas belong to the same market. Instead, the extent of a geographic market can be delineated by analysing regional price behaviour (Stigler & Sherwin, 1985). Price is an ideal measure for considering the extent of a geographic market because the level of competition is reflected in prices.

The concept of spatial market integration is based on the Takayama & Judge (1971) model of spatial competitive equilibrium in the neo-classical economy: if trade takes

[3] Two products are in the same market, i.e. are close substitutes in production, consumption or both, when their relative prices maintain a stable ratio and do not behave independently (Monke & Petzel, 1984). In this paper we do not, however, consider this aspect of market integration.

place between two markets, then competitive commodity arbitrage leads to an equilibrium in which prices differ only by inter-regional transportation costs, assuming there are no intra-regional transportation costs. Two regions are in the same economic market for a homogenous good if the prices for that good differ exactly by the inter-regional transportation costs (Sexton *et al.,* 1991). This concept is also denoted as "the law of one price" (LOP) between regions. Therefore, in long-run equilibrium, prices net of transportation costs (p_i ,p_j), should be equal in two locations, i.e. $p_{it}= p_{jt}$. Within the band measuring transaction costs (including costs of transportation, information search, etc.), arbitrage between regions is not profitable and prices in different regions will fluctuate independently of each other in response to localized changes in demand and supply conditions (Goodwin & Grennes, 1994). Because transportation costs are usually either minor or stable and the data are not easily available, their influence is often ignored in empirical work (exception: Baffes, 1991).

To clarify the connection between market integration and efficiency, segmented markets are less likely to be perfectly competitive and therefore may be subject to inefficiency. On the other hand, as market integration is not sufficient for Pareto-optimality of a competitive equilibrium, the conclusion that a market is fully integrated does not necessarily imply efficient spatial allocation. Thus, even if regional price differences exactly equal transaction costs, one cannot presume perfect competition, since this situation is equally consistent with spatial oligopoly (Faminow & Benson, 1990).

Traditionally, market integration has been analysed using correlation and single-equation regression analysis (see e.g. Stigler & Sherwin, 1985). Simple price correlation, however, does not necessarily imply any fundamental interrelationship. For example, two prices may exhibit similar deterministic trends. Because economic time series are often non-stationary, it is essential to study time series properties, i.e. unit roots and possible cointegration, prior to model building (Engle & Granger, 1987, Banerjee *et al.,* 1993).

Ravallion (1986) was the first to use error-correction modelling in studying market integration. Recently, cointegration tests have been used by several authors to study market integration for different commodities (e.g. Goodwin & Scroeder (1991) on U.S. cattle markets, Alexander & Wyeth (1994) on Indonesian rice markets, and Bessler & Fuller (1992) on U.S. wheat markets). However, a shortcoming of these studies is that they directly assume exogeneity of regional prices without testing for it. By contrast, simultaneity of different prices is allowed in Johansen's (1988, 1995) multivariate cointegration VAR model. This method has been used, for example, by Silvapulle & Jayasuriya (1994) to study rice market integration in the Philippines.

There have been few econometric studies of the forest sector that deal with market integration. Uri & Boyd (1990) studied interdependencies between softwood lumber markets in the U.S. using instantaneous Granger-causality tests. Multivariate cointegration analysis has been applied in testing the law of one price in sawnwood markets by Jung & Doroodian (1994) and recently by Hänninen (1998). Thorsen (1998) has studied the integration of timber markets in Scandinavia by testing the law of one price between different countries, and concluded that the strong law of one price holds between spruce sawlog markets. Murray & Wear (1998) analysed integration of lumber markets in the Pacific Northwest and the U.S. South using correlation analysis and the static form of the cointegration method developed by Engle & Granger (1987).

Methods of Analysis

The distinction between stationary and non-stationary data in economic analyses has become widely recognized during the 1990s (see e.g. Banerjee *et al.*, 1993). The traditional approach for testing non-stationarity of time series has been to use Augmented-Dickey-Fuller unit-root tests (Dickey & Fuller, 1979). As introduced by Engle & Granger (1987), cointegration is a statistical property of data that can describe long-run co-movement between economic time series. Cointegrated time series share the property that there exists a common equilibrium level to which their fluctuations have a tendency to revert.

During the 1990s, Johansen's (Johansen 1988; 1995) multivariate cointegration method became more popular than other methods for testing cointegration. Testing is based on an unrestricted p- dimensional VAR model, which can be formulated in error-correction form as

$$\Delta x_t = \Gamma_1 \Delta x_{t-1} +,\ldots,+ \Gamma_{k-1} \Delta x_{t-k+1} + \Pi x_{t-k} + \mu + \Phi D_t + \varepsilon_t, \quad (t = 1,\ldots,T) \qquad (1)$$

where x_t is a $(p \times 1)$ vector of variables in the system (Johansen & Juselius, 1990). The constant term (μ) can be restricted to the cointegrating space to represent no linear trend in the data. Seasonal dummies (D) can be included in the analysis when using quarterly or monthly data. Introduction of sufficient lags (k) is necessary for a well-behaved error term of NID(0,Ω). The rank of the long-run matrix, $\Pi = \alpha\beta'$, determines the number of cointegrating vectors in the system. The columns of β are the cointegrating vectors, which represent stationary linear combinations of variables x_t. The respective columns of α's give the weights with which the error-correction terms enter each equation, indicating the speed of adjustment to equilibrium. The likelihood ratio-test (a trace test) was derived by Johansen (1988) to test for rank, i.e. the number of (stationary) vectors, present in the cointegration space.

In testing for market integration with four different regions (p=4), we use both the cointegration rank test and the linear restriction test. If there is cointegration between the prices, the number of cointegration vectors revealed by the rank test indicates the degree of market integration. More precisely, full market integration requires p–1 cointegrating vectors among p prices (Goodwin & Grennes, 1994, p. 116). Thus, if we find that $r = p$–1, the implication is that we can solve for p–1 prices in terms of the pth price. In our case, if there are three cointegrating vectors, we have empirical evidence consistent with full market integration. Hence, stumpage price differentials between different geographic regions would be stationary in the long-run and there would be a national market for roundwood in Finland. Alternatively, if the estimated rank (r) is less than p–1, the degree of market integration is lower and the geographical market structure of a certain wood assortment cannot be characterized as a single market.

One of the main advantages of the Johansen method is that economic hypotheses can be formulated as linear restrictions and tested using likelihood ratio tests (Johansen & Juselius, 1990, 1992). If the hypothesis of full market integration is not rejected, it is possible to expand the analysis to test the strong version of the LOP (e.g. Buongiorno & Uusivuori, 1992), i.e. strict proportionality of prices in different regions. This is done by restricting the cointegration space so that the coefficients for two individual prices in an estimated cointegrating vector are equal to each other but are of opposite sign in the long-run. With four regional prices in each of our four price systems, and assuming three cointegration vectors in the data, we can use the following β matrix which embodies the restriction to test the null hypothesis of full market integration as:

$$\beta = H\varphi = \begin{bmatrix} 1 & 1 & 1 \\ -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{bmatrix} \varphi, \tag{2}$$

where H is a design matrix giving the restrictions on the β matrix and φ is a (3×3) matrix of the parameters reduced by means of H.[4] In this case the likelihood ratio statistics are distributed as $\chi^2(r)$.

It is of particular interest to test whether the origins of long-run equilibrium relations are reflected in the price changes of the largest wood-using regions, so that the prices of the dominant regions represent the driving forces behind the whole market. In empirical analysis, directions of price interrelationships between regions are tested with a weak exogeneity test in cointegration space (see Johansen, 1995; Doornik & Hendry, 1994). A variable is called weakly exogenous if it does not adjust to deviations from any equilibrium relation in the short-run, i.e. the restriction we test here is that the respective $á_i$ loading in cointegration analysis is zero (for more details, see Johansen, 1995, p.77–78).

[4] Under the null-hypothesis of full market integration it does not make a difference how the columns of β are ordered when we impose restrictions on its structure.

Finally, although the theoretical concept of market integration mainly applies to studying the long-run equilibrium price relationships, the methodology we use, i.e. the error-correction model, also facilitates testing for market integration in the short-run (e.g. Ravallion, 1986). It has also been argued that market analysis is incomplete unless it shows how quickly price differential between different areas reach equilibrium values (Silvapulle & Jayasuriya, 1994). As the error-correction representation (e.g. Engle & Granger, 1987) introduces lagged relationships into the dynamic specification of the price systems, instantaneous correlation between the prices for dominant (weakly exogenous) markets and the prices for other markets can not be fully captured if the error-correction terms have an effect on the dependent prices. Consequently, it is possible to test the significance of lagged price and equilibrium relationships in the models, and to evaluate the existence of one-to-one relationships between the dependent prices and the weakly exogenous price(s) also in the short-run. In empirical analysis, results from weak exogeneity tests are used to formulate a more parsimonious vector error-correction model, excluding equations for the prices for which the exogeneity hypothesis was not rejected. Contemporaneous values of these variables are included as explanatory variables in the dynamic models, together with lagged error-correction terms.

TIME SERIES DATA

In the empirical analysis we used average regional stumpage prices for the following wood assortments: pine sawlogs, spruce sawlogs, pine pulpwood and spruce pulpwood. Finland was divided into four separate regions by Forestry District boards; i.e. southern (District boards 1–6), eastern (District boards 7–12), western (District boards 13–15) and northern Finland (District boards 16–19), representing the separation of country in regional price recommendation areas at the end of the period studied. During the research period the respective shares of the regions in traded volumes have been on average 28, 46, 12 and 13 per cent, eastern Finland being by far the largest wood-consuming region. A more regionally disaggregated division, for example by all 19 Forestry District boards, could not be considered because it would lead to a system of overly large dimensions for analytical purposes.

Monthly time series covering the period from October 1985 to March 1996 were used (T=126). To check the robustness of our results, we also tested for market integration by dividing the sample into two sub-samples and comparing the test results. Data were obtained from the online forestry statistics of the Finnish Forest Research Institute (METINFO). The nominal stumpage prices were deflated by the domestic wholesale price index, as in previous roundwood market studies for Finland (e.g. Kuuluvainen *et al*., 1988; Hetemäki & Kuuluvainen, 1992), in order to remove the effects of inflation. Logarithmic forms of series were used in the statistical analysis.

Wood transportation costs in Finland are non-negligible; it is estimated that transportation costs account for close to one-third of the pulpwood costs at the mill. However, unlike in most European countries, the largest share of roundwood entering the market in Finland, about 70 per cent, is sold as stumpage. Due to this, wood prices in Finland are largely determined in the stumpage sector of the market. Since transportation costs are relatively constant over time compared to wood prices, and there are inadequate time series data, transportation costs have not been incorporated in this analysis.

RESULTS

In Figure 1, regional stumpage prices are presented by wood assortment. Similar business cycles are found in all stumpage assortments, and no significant price divergence can be visually detected from the graphs. We started the statistical analysis by testing for the unit roots in four stumpage assortments by four different regions, i.e. in sixteen prices altogether. Augmented Dickey-Fuller (ADF) tests indicated that the levels of all sixteen price series were non-stationary. On the other hand, the first differences of all prices were stationary (Table 1). The reported test statistics were obtained from a model which included a constant, a trend and three lags, but it seems that the conclusions hold regardless of the inclusion of a trend and a constant or of the number of lags used (from 1 to 6).

Since the price series were non-stationary, we proceeded to test for cointegration between them. Using Johansen's cointegration analysis, VAR models were formulated for each wood assortment. Thus we had four price

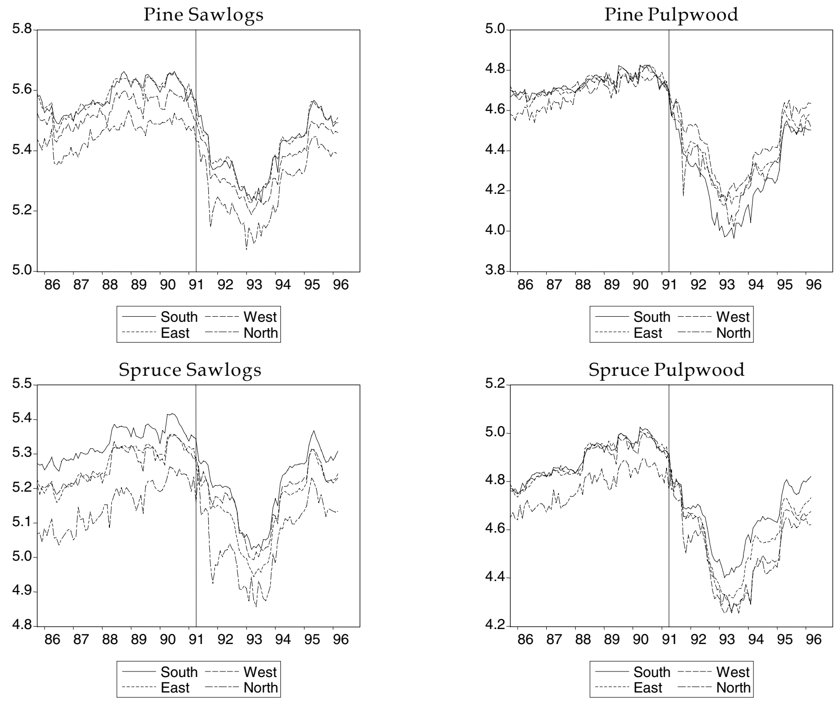

FIGURE 1. REGIONAL STUMPAGE PRICES.

Graphs of the regional stumpage prices (real prices in logs) where vertical line indicates the end of collective stumpage price recommendations in Spring 1991.

TABLE 1. ADF-TEST RESULTS.

The table shows ADF-test results for roundwood prices by regions in Finland from model specification including a constant, a trend variable and three lags.

PRICES	ADF-TEST BY[i] REGIONAL PRICES			
	South	*East*	*West*	*North*
Levels				
Spruce pulpwood	−1.33	−1.48	−1.48	−1.57
Spruce sawlogs	−1.55	−1.58	−1.88	−1.67
Pine pulpwood	−1.08	−0.92	−1.08	−1.27
Pine sawlogs	−1.41	−1.32	−1.18	−1.22
1st Differences				
Spruce pulpwood	−4.31*	−4.44*	−4.34*	−4.86*
Spruce sawlogs	−4.21*	−4.46*	−4.46*	−5.18*
Pine pulpwood	−4.20*	−4.69*	−5.07*	−6.12*
Pine sawlogs	−4.24*	−4.80*	−4.82*	−5.17*

[i] * denotes the rejection of null hypothesis of nonstationarity. The critical value for the ADF test −4.03 at 5 % level (see e.g. Dickey & Fuller, 1979).

systems, each including four prices. The presence of a deterministic trend in cointegration vectors was checked using F-tests, and results favoured the specification with no linear trend in the data. To define the correct dimension of the VAR models for cointegration analysis, a testing procedure incorporating sequential decreases in the number of lags offered by PcFiml was used (see Doornik & Hendry, 1994). This procedure as well as the diagnostic tests for the residuals of each equation and the corresponding vector test statistics (Table 2) indicated that a VAR model with three lags (i.e. $p = 4$, $k = 3$) would be an adequate statistical representation of our price data. It should be noted that the null-hypothesis of residual normality was rejected in all the price equations. However, according to Gonzalo (1994), the results for Johansen's cointegration analysis should not be biased despite of residual non-normality.

Degree of market integration was tested by estimating the rank in these four price systems using the Johansen procedure. Unrestricted cointegrating vectors and their respective loadings are presented in Table 3. According to the rank test (Table 4), the hypothesis of full market integration was acceptable only in the case of pine sawlog prices, where trace tests indicated rank, r, was 3. For spruce sawlogs and pine pulpwood, the indicated rank was 2. For spruce pulpwood, $r = 2$ could also be accepted because the trace-test value was very close to the critical value, indicating two cointegrating vectors.

Further, it was possible to test explicitly for full market integration (under r =3) in the pine sawlog model by using the linear restrictions shown in equation [2] (Table 4). For the other three wood assortments, the null hypothesis of full market integration could not be tested because they failed to meet the rank $r = 3$ condition required for the hypothesis to hold. For pine sawlogs, the likelihood ratio test for strict price proportionality in cointegration vectors was not rejected, which indicates that in the long-run even the strong law of one price holds between the regions.

After testing for full market integration, we proceeded to test for weak exogeneity of individual prices in each wood assortment (Table 5). In the pine sawlog system, the

TABLE 2. MISSPECIFICATION TESTS FOR RESIDUALS.

Misspecification tests for residuals from Johansen's cointegration estimation of stumpage price models by four different wood assortments with three lags and seasonal dummies in each system.

EQUATION	TEST FOR RESIDUALS AND STANDARD ERRORS			
	Autocor-relation [a] $F_{AR}(7,103)$	Heteroske-dasticity [b] $F_{ARCH}(7,96)$	Norma-lity [c] $\chi^2(2)$	Standard errors σ_e
Pine sawlogs				
ΔSouth	1.07 [0.39]	0.16 [0.99]	33.9 [0.00]*	0.02
ΔEast	0.51 [0.82]	0.33 [0.94]	54.3 [0.00]*	0.02
ΔWest	1.02 [0.42]	0.40 [0.90]	22.8 [0.00]*	0.02
ΔNorth	1.03 [0.42]	0.17 [0.99]	39.1 [0.00]*	0.03
System	$VF_{AR}(112,306)$ = 0.91[0.72]		$V\chi^2(8)$ = 34.5 [0.00]*	
Spruce sawlogs				
ΔSouth	1.02 [0.42]	0.24 [0.98]	10.8 [0.01]*	0.02
ΔEast	0.94 [0.48]	0.38 [0.91]	49.8 [0.00]*	0.02
ΔWest	0.80 [0.59]	0.43 [0.88]	14.4 [0.00]*	0.02
ΔNorth	0.26 [0.97]	2.03 [0.06]	42.9 [0.00]*	0.03
System	$VF_{AR}(112, 316)$ = 0.97[0.57]		$V\chi^2(8)$ = 80.1 [0.00]*	
Pine pulpwood				
ΔSouth	1.48 [0.18]	0.23 [0.98]	28.3 [0.00]*	0.03
ΔEast	0.40 [0.50]	0.16 [0.99]	74.8 [0.00]*	0.03
ΔWest	1.03 [0.40]	0.30 [0.95]	49.8 [0.00]*	0.05
ΔNorth	1.30 [0.29]	0.21 [0.98]	22.9 [0.00]*	0.03
System	$VF_{AR}(112, 316)$ = 0.86 [0.57]		$V\chi^2(8)$ = 85.6 [0.00]*	
Spruce pulpwood				
ΔSouth	1.23 [0.29]	0.60 [0.76]	28.9 [0.00]*	0.02
ΔEast	0.74 [0.64]	0.58 [0.76]	61.7 [0.00]*	0.03
ΔWest	0.75 [0.63]	0.45 [0.87]	39.2 [0.00]*	0.03
ΔNorth	0.77 [0.62]	1.46 [0.19]	7.8 [0.02]*	0.04
System	$VF_{AR}(112, 316)$ = 1.25 [0.07]		$V\chi^2(8)$ = 23.0 [0.01]*	

Note: Values in square brackets are marginal significance levels and * indicates that the null hypothesis is rejected at the 5 percent level. [a] Autocorrelation of the residuals of individual equations and a whole system VF_{AR} was examined using the F–form of the Lagrange-Multiplier (LM) test, which is valid for systems with lagged dependent variables. [b] Heteroskedasticity was tested using the F-form of the LM test against 7th order autoregressive conditional heteroskedasticity. [c] Normality of the residuals of individual equations and a whole system $V\chi^2$ was tested with the Doornik-Hansen test (Doornik & Hendry, 1994). For further details and test references, see Doornik & Hendry (1994).

TABLE 3. NORMALIZED UNRESTRICTED EIGENVECTORS AND THEIR WEIGHTS IN PINE AND SPRUCE SAWLOG AND PULPWOODSYSTEMS.

	EIGENVECTORS				WEIGHTS			
	β_1	β_2	β_3	β_4	α_1	α_2	α_3	α_4
Pine sawlogs								
South	1.00	−1.77	−0.63	−0.27	−0.30	0.15	−0.04	−0.01
East	−1.32	1.00	−1.38	0.87	0.04	−0.10	0.02	−0.01
West	1.20	1.28	1.00	1.89	−0.20	−0.24	−0.17	−0.01
North	−0.85	−0.47	1.02	1.00	0.27	0.19	−0.33	−0.01
Spruce sawlogs								
South	1.00	−0.83	−4.84	2.60	0.04	0.01	−0.01	0.00
East	9.33	1.00	2.13	−0.32	0.02	−0.27	−0.03	0.00
West	−15.56	0.10	1.00	1.87	0.05	−0.10	−0.04	0.00
North	2.60	−0.32	1.86	1.00	−0.00	0.46	−0.10	0.00
Pine pulpwood								
South	1.00	−0.98	−0.26	2.08	−0.04	0.01	−0.17	−0.01
East	−4.21	1.00	−0.35	0.09	0.03	−0.32	−0.06	−0.00
West	0.25	0.15	1.00	−1.84	−0.02	−0.24	−0.28	−0.00
North	2.76	0.13	−0.18	1.00	−0.22	−0.48	−0.01	−0.00
Spruce pulpwood								
South	1.00	−0.52	−3.24	4.80	0.06	0.17	0.04	0.01
East	−0.07	1.00	2.04	−2.72	0.16	−0.02	0.08	0.01
West	0.58	−0.56	1.00	−3.34	0.14	0.49	−0.23	0.01
North	−1.59	0.07	−0.71	1.00	0.39	0.22	0.14	0.00

test statistics for the null hypothesis of weak exogeneity revealed that the stumpage price in eastern Finland was weakly exogenous to prices in the south, west and north. This result can be interpreted to mean that eastern Finland has been the origin of stochastic trends driving the market for pine sawlogs.[5] For spruce sawlogs, weak exogeneity of the price in northern Finland was observed. We suspect, however, that this is more likely related to the higher price variation associated with the low spruce

[5] E.g. Blank & Schmiesing (1988) have suggested that market information flows and product flows should move in opposite directions since information flows originate on the demand side while product flows originate on the resource supply side. This pattern is consistent with demand-side causality between two prices. As pointed out by one referee, results from weak exogeneity tests could be interpreted in light of separating prices for different wood assortments originating from either supply or demand regions. Unfortunately, assortment specific data on interregional trade flows of wood are available only for the year 1994, which does not give us sufficient information to separate the markets into supply and demand regions.

TABLE 4. RESULTS FROM THE COINTEGRATION TEST.
Cointegration test results for regional stumpage price systems by each wood assortment (pine sawlogs, spruce sawlogs, pine pulpwood and spruce pulpwood).

	COINTEGRATION RANK TEST				FULL MARKET INTEGRATION TEST
H_o:	$r = 0$	$r \leq 1$	$r \leq 2$	$r \leq 3$	H_o: $r = 3^{ii}$
Pine sawlogs					
Eigenvalues	0.30	0.22	0.19	0.01	3.18
Trace test value	103.5**	60.3**	28.5**	1.4	
95 %[i]	47.2	29.7	15.4	3.8	
Spruce sawlogs					
Eigenvalues	0.26	0.14	0.08	0.02	–
Trace test value	69.2**	32.3*	13.5	2.7	
95 %	47.2	29.7	15.4	3.8	
Pine pulpwood					
Eigenvalues	0.27	0.15	0.08	0.01	–
Trace test value	68.9**	30.7*	10.9	1.3	
95 %	47.2	29.7	15.4	3.8	
Spruce pulpwood					
Eigenvalues	0.19	0.14	0.07	0.01	–
Trace test value	55.9**	29.4	10.8	1.7	
95 %	47.2	29.7	15.4	3.8	

[i] Critical values from Johansen and Juselius (1990) and ** indicates significance at 1 % level and * at 5 % level.

[ii] Full market integration test (from eq. [2]) under r = 3, with the critical value $\chi^2(3) = 7.82$. ** (*) indicates rejection of full market integration hypothesis at 1 % (5 %) level.

sawlog quantities (below 5 % of total market) traded in northern Finland than to northern Finland being a truly price-leading region in the market. However, the second relationship originating in the main wood-using region, eastern Finland, was close to the 5 % critical value in the spruce sawlog system.

In the spruce pulpwood market, prices from southern and eastern Finland were found to be weakly exogenous with respect to other prices, which may indicate the dominant role of these regions in the Finnish pulpwood market. In the pine pulpwood market, prices in southern and western Finland were found to be weakly exogenous, which is again consistent with the importance of pulp production capacity in both of these regions. However,

TABLE 5. WEAK EXOGENEITY TESTS UNDER ESTIMATED COINTEGRATION RANK r.[1]

H_0: VARIABLE WEAKLY EXOGENOUS ($\alpha_i = 0$)	SOUTH	EAST	WEST	NORTH
Pine sawlogs, $r = 3$	11.08**	1.54	17.03**	14.20**
Spruce sawlogs, $r = 2$	18.67**	6.81*	17.74**	1.65
Pine pulpwood, $r = 2$	1.57	8.37*	2.99	21.08**
Spruce pulpwood, $r = 2$	2.14	5.79	9.58**	15.50**

[1] ** (*) indicates rejection of weak exogeneity at 1 % (5 %) level. According to the r used, critical $\chi^2(2)$ value is 5.99 and $\chi^2(3)=7.82$ at 5 % level.

the weak exogeneity of eastern Finland was rejected in pine pulpwood system, although the industry in eastern Finland is a main user of both domestic and imported pine pulpwood. [6]

In conclusion, results from weak exogeneity tests in Table 5 indicated that the revealed pattern of weakly exogenous prices broadly reflects the relative importance of regional markets, i.e. that price changes in the largest wood-using regions of eastern and southern Finland have a significant impact on the prices in western and northern Finland. On the other hand, the effect from the opposite direction was only true for two cases in spruce sawlog and pine pulpwood markets, indicating that the effects of smaller regions on larger ones are not equally important.

To account for a possible structural break in the market environment due to the collapse of nationwide stumpage price recommendation system, cointegration vectors were re-estimated using two sub-samples of data, 1985:10–91:02 and 1991:03–96:03 (see Appendix 1 for the estimated eigenvectors and the respective loadings). At least one cointegration relationship was present in all price systems in both time periods. For pine sawlogs, the rank test results $r = 3$ was very close to 5 % significance levels

[6] It might be noted that in the pine sawlog system, the results from the weak exogeneity tests were consistent with the estimated cointegrating rank, $r = 3$, and one weakly exogenous variable was represented by one common trend originating from eastern Finland. In pine and spruce pulpwood markets, the estimated cointegration rank, $r = 2$, was consistent with two common trends and two exogenous variables, and close to critical values, the same result of $r = 2$ was obtained in the spruce sawlog system as well.

TABLE 6. RESULTS FROM COINTEGRATION TEST.
Cointegration test results for regional stumpage price systems by each wood assortment (pine sawlogs, spruce sawlogs, pine pulpwood and spruce pulpwood) in 1985–91 and 1991–96.

	COINTEGRATION RANK TEST			
H_o:	$r = 0$	$r \leq 1$	$r \leq 2$	$r \leq 3$
Trace test 95 %	47.2	29.7	15.4	3.8
1985-91:				
Pine sawlogs				
Eigenvalues	0.36	0.32	0.19	0.02
Trace test value	66.26**	33.48**	14.63	1.64
Spruce sawlogs				
Eigenvalues	0.36	0.19	0.14	0.01
Trace test value	52.57*	23.69	10.38	1.06
Pine pulpwood				
Eigenvalues	0.27	0.24	0.20	0.05
Trace test value	54.48**	34.99*	17.36*	3.13
Spruce pulpwood				
Eigenvalues	0.37	0.27	0.21	0.04
Trace test value	65.82**	36.83**	17.17*	2.44
1991–96:				
Pine sawlogs				
Eigenvalues	0.51	0.27	0.24	0.04
Trace test value	81.89**	38.76**	19.49*	2.63
Spruce sawlogs				
Eigenvalues	0.28	0.23	0.14	0.04
Trace test value	46.76	26.99	11.24	2.16
Pine pulpwood				
Eigenvalues	0.37	0.30	0.17	0.05
Trace test value	64.37**	36.26**	14.34	3.00
Spruce pulpwood				
Eigenvalues	0.30	0.27	0.11	0.03
Trace test value	49.18*	27.93	8.79	1.84

in both periods (Table 6). The results for spruce sawlogs were also robust with respect to estimation period, indicating, at the 10 % significance level, only one cointegration vector in the data. By contrast, for pine and spruce pulpwood the hypothesis of full market integration was not rejected using the data for 1985–91. However, it was rejected in both wood assortments using the data for period 1991–96, indicating that integration of pulpwood markets has diminished during the 1990s in Finland. The effect of the price negotiation system on the pulpwood market is also consistent with the one obtained in a previous study (Toppinen & Kuuluvainen, 1997); it was found to increase traded pulpwood quantities in the Finnish roundwood market. However, it has to be borne in mind that there is a loss in the reliability of cointegration tests as they were weakened by the scarcity of data in the two sub-samples. Given the potentially low power of these tests in small samples (e.g. Johansen & Juselius, 1990), our conclusions regarding the decrease in the degree of pulpwood market integration remain somewhat speculative.

As rank test results for the two samples indicated the possibility of some change in the dynamics of stumpage price relationships, we will, in what follows, explicitly test for the existence of a structural break in 1991 using structural error-correction models. The effect of structural break is modelled by including a dummy variable in each model system, price observations after February 1991 taking the value one. Following error-correction methodology (see. e.g. Doornik & Hendry, 1994), equations for weakly exogenous prices (Table 5) are dropped from price systems, and contemporaneous price differences of them are used as independent variables together with lagged equilibrium price relationships obtained from cointegration analysis.

Results (reported in Appendix 2) indicate that all short-run models have well-behaved error structures and their residual standard errors are low. As expected, the hypothesis of short-run market integration cannot be accepted for any of the wood assortments, since at least one statistically significant cointegration vector enters each of the model systems. Instantaneous impacts of the prices for dominant (weakly exogenous) markets on the rest of the prices are not fully captured as coefficients of weakly exogenous prices are positive, but significantly below unity. However, the lead-lag relationships in the markets are short as the lagged first differences for one month (or two months in spruce pulpwood) were found to be sufficient to remove residual autocorrelation. Moreover, there seems to be no significant difference across wood assortments with respect to the level of short-run pricing efficiency. Adjustment to market equilibrium in individual price systems takes place in about half a year if evaluated by the average size of error-correction terms (see Appendix 2). Finally, the dummy variable taking into account a possible structural break in the market system was not statistically significant in any of the equations, validating the market integration test results obtained for the full period.

CONCLUDING REMARKS

In this study we analysed stumpage market integration in Finland by testing the existence and origin of long-run equilibrium relations among the prices in southern, eastern, western and northern Finland using monthly data for 1985–96. Following Goodwin & Grennes (1994), we assumed that if there is cointegration between prices, the number of cointegration vectors revealed by Johansen's (1995) rank test indicates the degree of market integration. In addition, short-run analysis of market integration was provided, incorporating the issue of a possible structural break due to the collapse of the nationwide stumpage price negotiation system in 1991.

In general, our results, from multivariate cointegration tests, indicated that the degree of roundwood market integration in Finland differs across wood assortments. The null hypothesis of full long-run market integration could be accepted only in the case of pine sawlogs and one common stochastic price trend was identified as originating in eastern Finland. For pine pulpwood and spruce sawlogs, the cointegration rank test indicated two separate cointegrating vectors and two common trends. For spruce pulpwood one or two cointegrating vectors were detected, depending on the level of significance used. With respect to pine and spruce pulpwood prices, southern Finland was found to be the driving region, as was western Finland in pine pulpwood prices and eastern Finland in spruce pulpwood prices. Thus, cointegration test results broadly supported the hypothesis that stumpage prices in the Finnish roundwood market are driven by the prices in the main wood-using regions, and that effects from smaller regions are of minor importance. Despite the collapse of the stumpage price recommendation system in

1991, regional stumpage prices continued to be cointegrated and the effect of the structural break in the market environment caused by the end of central price recommendation system was found to have no effect on any of the short-run models. Significant departures from the necessary conditions of short-run market integration were, however, detected for all four wood assortments.

Rejection of full long-run market integration in three out of four wood assortments indicates that Finnish roundwood markets, with the exception of that for pine sawlogs, may be subject to some degree of market inefficiency due to regional market segmentation. Results from the short-run analysis, however, indicate that price differentials between different areas typically reach their equilibrium values quickly, and eventually, due to cointegration between regional prices, price differences converge to their long-run equilibrium levels. Markets for stumpage in Finland are therefore relatively well integrated and any serious problems in modelling aggregate demand for, and supply of, different timber species should not arise, especially when data of less than monthly frequency are used.

In conclusion, our results demonstrate that regional price relationships in different wood markets can be more complex than commonly assumed. Our results also illustrated the advantages of using highly disaggregated price data, e.g. by assortments, regions and time, for analysing roundwood markets. A similar modelling approach and use of multivariate cointegration analysis could provide equally useful tools in analysing the integration of wood markets in other countries as well. Unfortunately, in most countries this is problematic due to lack of relevant (monthly or quarterly) statistics on stumpage prices.

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REFERENCES

Alexander, C. & Wyeth, J., 1994. Cointegration and Market Integration: An Application to the Indonesian Rice Karket. *The Journal of Development Studies*, 30: 303–328.

Baffes, J., 1991. Some Further Evidence on the Law of One Price: The Law of One Price Still Holds. *American Journal of Agricultural Economics*, 73: 1264–1273.

Banerjee, A., Dolado, J., Galbraith, J. & Hendry, D., 1993. *Co-integration, Error-correction, and the Economic Analysis of Non-stationary Data* (Oxford:Oxford University Press).

Bessler, D. & Fuller, S., 1992. Cointegration between U.S. Wheat Markets. *The Journal of Regional Science*, 33: 481–501.

Blank, S. & Schmiesing, B., 1988. Modeling of Agricultural Markets and Prices Using Causality and Path Analysis. *North Central Journal of Agricultural Economics*, 10:35–48.

Buongiorno, J. & Uusivuori, J., 1992. The Law of One Price in the Trade of Forest Products: Co-integration Tests for U.S. Exports of Pulp and Paper. *Forest Science*, 38: 539–553.

Dickey, D. & Fuller, W.A., 1979. Distribution of the Estimators for Autoregressive Time Series with a Unit Root. *Journal of American Statistical Association*, 74: 427–431.

Doornik, J. & Hendry, D., 1994. *PcFiml 8.0. Interactive Econometric Modelling of Dynamic Systems.* Institute of Economics and Statistics University of Oxford. International Thomson Publishing. 436 p. ISBN 1-850-32113-2.

Engle, R. & Granger, C.W.J., 1987. Cointegration and Error-correction: Representation, Estimation andTesting. *Econometrica*, 55: 251–276.

Faminow, M. & Benson, B., 1990. Integration of Spatial Markets. *American Journal of Agricultural Economics,* 72: 49–62.

Gonzalo, J., 1994. Five Alternative Methods of Estimating Long-run Equilibrium Relationships. *Journal of Econometrics,* 55: 203–233.

Goodwin, B. & Schroeder, B., 1991. Cointegration Tests and Spatial Price Linkages in Regional Cattle Markets. *American Journal of Agricultural Economics*, 73: 452–464.

Goodwin, B. & Grennes, T.J., 1994. Real Interest Rate Equalization and the Integration of International Financial Markets. *Journal of International Money and Finance,* 13: 107–124.

Hetemäki, L. & Kuuluvainen, J., 1992. Incorporating Data andTheory in Roundwood Supply and Demand Estimation. *American Journal of Agricultural Economics,* 74: 1010–1018.

Hänninen, R., 1998. The Law of One Price in United Kingdom Soft Sawnwood Imports — a Cointegration Approach. *Forest Science*, 44: 17–23.

Johansen, S., 1988. Statistical Analysis of Cointegration Vectors. *Journal of Economic Dynamics and Control,* 12: 231–254.

Johansen, S., 1995. *Likelihood Based Inference in Cointegrated Vector Autoregressive Models* (Oxford: Oxford University Press).

Johansen, S. & Juselius, K., 1990. Maximum Likelihood Estimation and Inference on Cointegration — with Applications to the Demand for Money. *Oxford Bulletin of Economics and Statistics*, 52: 169–210.

Johansen, S. & Juselius, K., 1992. Structural Tests in a Multivariate Cointegration Analysis of the PPP and the UIP for UK. *Journal of Econometrics,* 53: 211–244.

Jung, C. & Doroodian, K., 1994. The Law of One Price for U.S. Softwood Lumber: A Multivariate Cointegration Test. *Forest Science*, 40: 595–600.

Kuuluvainen, J., Hetemäki, L., Ollonqvist, P., Ovaskainen, V., Pajuoja, H., Salo, J., Seppälä, H. & Tervo, M., 1988. The Finnish Roundwood Market: an Econometric Analysis. *Finnish Economic Papers*, 1: 191–201.

Kuuluvainen, J. & Ovaskainen, V., 1994. Yksityismetsänomistajien puunmyynteihin vaikuttavat tekijät. In *Structural Change in NIPF Ownership and the Use of Forests in Finland*, edited by V. Ovaskainen & J. Kuuuluvainen, Metsäntutkimuslaitoksen tiedonantoja 484, pp. 45–59 (in Finnish).

Monke, E. & Petzel, T., 1984. Market Integration: An Application to International Trade in Cotton. *American Journal of Agricultural Economics,* 66: 481–487.

Murray, B. & Wear, D., 1998. Federal Timber Restrictions and Interregional Arbitrage in U.S. Lumber. *Land Economics,* 74: 76–91.

Ravallion, M., 1986. Testing Market Integration. *American Journal of Agricultural Economics,* 68: 102–109.

Silvapulle, P. & Jayasuriya, S., 1994. Testing for Philippines Rice Market Integration: A Multiple Cointegration Approach. *Journal of Agricultural Economics,* 45: 369–380.

Sexton, R., Kling, C. & Carman, H., 1991. Market Integration, Efficiency of Arbitrage, and Imperfect Competition: Methodology and Application to U.S. Celery. *American Journal of Agricultural Economics*, 73: 568–580.

Stigler, G. & Sherwin, R., 1985. The Extent of the Market. *Journal of Law & Economics*, XXVIII:555–585.

Takayama, T. & Judge, G., 1971. *Spatial and Temporal Price and Allocation Models* (Amsterdam: North-Holland Publishing Co).

Thorsen, B., 1998. *Spatial Integration in the Nordic Timber Market:Long-run Equilibria and Short-run Dynamics* (Forthcoming in Scandinavian Journal of Forest Research, Vol 13).

Toppinen, A. & Kuuluvainen, J., 1997. Structural Changes in Sawlog and Pulpwood Markets in Finland. *Scandinavian Journal of Forest Research,* 12: 382–389.

Uri, N. & Boyd, R., 1990. Considerations on Modelling the Market for Softwood Lumber in the United States. *Forest Science,* 36: 680–692.

Uusivuori, J. & Mykkänen, R., 1996. *European Competition Policy in the Finnish Forest Sector*. Pellervo Economic Research Institute, Reports and Discussion Papers 138.

Västilä, S. & Peltola, A., 1997. Puun kulkuvirrat ja puun hankinnan keskittyminen 1994. Metsäntutkimuslaitoksen tiedonantoja 638. 21 p. + liitteet. ISBN 951–40–1564–9. (in Finnish)

APPENDIX 1

Normalized unrestricted eigenvectors and their weights in pine and spruce sawlog and pulpwood systems in 1985–91 and 1991–96.

	EIGENVECTORS				WEIGHTS			
	β_1	β_2	β_3	β_4	α_1	α_2	α_3	α_4
1985–91								
Pine Sawlogs								
South	1.00	−0.70	−1.76	1.33	−0.17	0.01	0.10	−0.03
East	−2.83	1.00	0.30	−0.10	0.02	−0.53	−0.01	−0.03
West	2.58	0.48	1.00	−0.53	−0.27	−0.40	−0.26	−0.01
North	−0.26	−0.86	0.69	1.00	0.13	0.39	−0.24	−0.03
Spruce Sawlogs								
South	1.00	−0.37	−17.69	6.32	0.11	−0.01	0.00	−0.01
East	1.63	1.00	6.42	−4.87	0.21	−0.36	−0.01	−0.01
West	−3.41	−0.20	1.00	−1.25	0.37	0.25	−0.00	−0.00
North	0.55	−0.20	11.04	1.00	0.01	0.63	−0.03	−0.01
Pine Pulpwood								
South	1.00	0.30	−1.54	3.28	−0.26	−0.22	0.07	−0.02
East	−1.33	1.00	1.05	0.69	−0.16	−0.24	−0.28	−0.02
West	1.33	−0.70	1.00	−2.57	−0.43	0.19	−0.21	−0.00
North	−0.69	−0.53	0.01	1.00	0.27	0.28	0.03	−0.02
Spruce Pulpwood								
East	1.00	−0.57	5.49	2.42	0.31	−0.14	−0.04	−0.03
South	0.57	1.00	−2.07	−1.06	0.40	−0.71	−0.02	−0.01
Continued...								
West	−2.01	−0.18	1.00	−1.73	0.65	0.20	−0.04	0.00
North	0.16	−0.19	−5.03	1.00	0.55	0.43	0.06	−0.04
1991–96:								
Pine Sawlogs								
South	1.00	1.30	−2.81	0.16	−0.36	0.03	0.12	0.01
East	−0.94	1.00	2.42	0.50	0.09	−0.03	−0.09	0.01
West	1.27	−1.64	1.00	−8.06	−0.21	0.23	−0.06	0.01
North	−1.23	−0.63	−0.46	1.00	0.48	0.41	0.21	0.01
Spruce Sawlogs								
South	1.00	−0.36	0.12	12.47	−0.19	0.73	−0.00	0.01
East	−0.57	1.00	−5.11	−21.07	0.34	0.51	0.01	0.01
West	−0.50	−0.84	1.00	2.36	0.38	0.84	−0.02	0.00
North	−0.03	0.10	4.09	1.00	0.10	0.18	−0.11	0.01
Pine Pulpwood								
South	1.00	−1.20	0.46	1.64	−0.19	0.56	0.03	0.02
East	0.11	1.00	−0.94	0.97	0.18	0.01	0.17	0.03
West	−0.52	0.14	1.00	−5.57	0.32	0.25	−0.19	0.02
North	−0.60	−0.25	−0.32	1.00	1.25	0.84	0.21	0.01
Spruce Pulpwood								
East	1.00	0.41	0.33	−11.13	−0.38	0.23	−0.16	−0.01
South	−0.53	1.00	−0.63	13.16	−0.13	0.13	−0.10	−0.01
West	−0.62	0.00	1.00	0.54	0.34	0.28	−0.15	−0.01
North	0.23	−1.46	−0.86	1.00	−0.09	0.38	0.17	−0.01

APPENDIX 2

Results for the short-run error-correction models (t-statistics in parentheses below coefficients). D denotes variables in first differences, *ECM*'s are lagged error-correction terms obtained from cointegration analysis and *S19913* is a step-dummy variable taking value one after February 1991.

PINE SAWLOGS	*DSouthern Price*	*DWestern Price*	*DNorthern Price*
Constant	−0.00 (−0.03)	0.06 (2.99)	−0.15 (−4.81)
DSouthern $Price_{t-1}$	−0.22 (−2.61)	−0.05 (−0.61)	−0.12 (−0.88)
DWestern $Price_{t-1}$	0.14 (1.65)	−0.10 (−1.14)	−0.03 (−0.24)
DNorthern $Price_{t-1}$	0.02 (0.28)	0.01 (0.12)	0.05 (0.53)
DEastern Price	0.75 (12.04)	0.78 (12.43)	0.75 (7.45)
$ECM1_{t-1}$	−0.29 (−5.26)	−0.21 (−3.68)	0.21 (2.27)
$ECM2_{t-1}$	0.20 (3.70)	−0.16 (−3.00)	0.26 (3.00)
$ECM3_{t-1}$	−0.07 (−1.80)	−0.17 (−4.13)	−0.35 (−5.25)
S199103	−0.00 (−0.37)	−0.00 (−0.84)	0.01 (1.08)
σ	0.01	0.01	0.02
$F_{AR}(7, 106)$	1.54	0.71	0.21
Wald-test	*S199103* = 0	2.91 (p = 0.40)	

SPRUCE SAWLOGS	*DSouthern Price*	*DEastern Price*	*DWestern Price*
Constant	0.44 (4.20)	0.14 (1.20)	0.58 (4.84)
DSouthern $Price_{t-1}$	−0.60 (−4.63)	−0.26 (−1.79)	−0.17 (−1.14)
DEastern $Price_{t-1}$	0.53 (4.0)	0.34 (2.35)	0.31 (2.09)
DWestern $Price_{t-1}$	0.29 (2.72)	0.15 (1.23)	0.01 (0.11)
DNorthern Price	0.14 (3.49)	0.23 (4.99)	0.23 (5.05)
$ECM1_{t-1}$	0.03 (4.71)	0.02 (2.23)	0.04 (5.66)
$ECM2_{t-1}$	−0.09 (−0.83)	−0.39 (−3.25)	−0.21 (−1.70)
S199103	0.00 (0.30)	−0.00 (−0.41)	0.00 (0.08)
σ	0.02	0.02	0.02
$F_{AR}(7, 106)$	1.65	0.56	0.56
Wald-test	*S199103* = 0	1.03 (p = 0.79)	

PINE PULPWOOD	*DEastern Price*	*DNorthern Price*
Constant	0.52	0.57
	(5.19)	(2.87)
DEastern Price$_{t-1}$	0.13	−0.06
	(1.47)	(−0.36)
DNorthern Price$_{t-1}$	−0.01	−0.12
	(−0.37)	(−1.24)
DSouthern Price	0.48	0.37
	(7.09)	(2.79)
DWestern Price	0.23	0.31
	(3.17)	(2.18)
ECM1$_{t-1}$	0.07	−0.16
	(3.43)	(−4.03)
ECM2$_{t-1}$	−0.32	−0.52
	(−4.54)	(−3.74)
S199103	−0.00	0.01
	(−0.37)	(0.49)
σ	0.02	0.04
$F_{AR}(7, 107)$	1.09	1.86
Wald-test	S199103=0	0.0001 (p=1.00)

SPRUCE PULPWOOD	*DWestern Price*	*DNorthern Price*
Constant	0.02	0.06
	(1.94)	(4.28)
DWestern Price$_{t-1}$	−0.23	0.13
	(−2.69)	(1.10)
DNorthern Price$_{t-1}$	0.16	−0.21
	(2.09)	(−1.89)
DWestern Price$_{t-2}$	−0.17	−0.03
	(−2.15)	(−0.25
DNorthern Price$_{t-2}$	0.11	−0.02
	(1.78)	(−0.20)
DSouthern Price	0.52	0.34
	(3.79)	(1.77)
DEastern Price	0.47	0.31
	(3.81)	(1.76)
ECM1$_{t-1}$	0.10	0.32
	(2.04)	(4.42)
S199103	−0.00	0.00
	(−0.29)	(0.19)
σ	0.02	0.03
$F_{AR}(7, 106)$	4.00*	1.27
Wald-test	S199103=0	0.0001 (p=1.00)