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COINTEGRATION IN TESTING MARKET INTEGRATION

An Empirical Analysis of Finnish Roundwood Markets

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ABSTRACT

Previous econometric studies on the Finnish roundwood market have assumed that there is a national market for timber, where stumpage prices and quantities are determined. This assumption was relevant especially during the 1980s, when the collective nationwide stumpage price agreement system existed in Finland. However, institutional changes in the negotiation system during the 1990s raised the need to explicitly test this assumption with recent data. In this paper we analyse long-run relationships in the Finnish roundwood markets between four geographic regions. The division of the country into southern, eastern, western and northern Finland is based on the geographic regions of stumpage price negotiations in 1995–1996.

First, the aim of our study is to analyse whether regional price development between various wood assortments, in our case pine and spruce sawlogs and pine and spruce pulpwood, vary from each other. Using Johansen's multivariate cointegration tests and monthly stumpage prices for 1985–96, a hypotheses full market integration could not be rejected for pine sawlogs, but the hypotheses was rejected for other assortments. Acceptance of full market integration only in pine sawlog markets may be due to relatively lower market concentration in these markets, i.e. there exists a number of independent sawmills enhancing competition in the market. Although independent sawmills are also active in the spruce sawlog market, the relatively smaller share of spruce in the forest resources in northern Finland could differentiate these markets.

Second, direction of causality between regional stumpage prices (assortment specific markets) was also studied in the cointegration framework by testing the hypothesis of weak exogeneity of individual variables. According to the results, prices of pine sawlogs and spruce pulpwood in eastern Finland were found to be weakly exogenous to the other prices in other regions. In pine and spruce pulpwood markets, the source of price fluctuation was found to be southern Finland. Thus, causation between regional prices mainly originates in the wood using regions, likely reflecting that demand rather than supply forces are driving the market.

Our results suggest that further studies would be useful in this field. Beginning the year 1997, the negotiations on stumpage price expectations started to take place between sellers of wood and individual forest industry companies. This may decrease the role of regional factors in the market and enhance competition by splitting the bargaining power in negotiations. The effects of this structural change on relative regional stumpage prices is therefore an interesting possibility to extend this work.

Keywords: *regional stumpage market, stumpage prices, market integration, cointegration analysis*

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TIIVISTELMÄ

Raakapuumarkkinoiden tutkimuksessa on tavallisesti oletettu, että Suomi on yhtenäinen markkina-alue. Tämän olettamuksen testaamiseksi tässä tutkimuksessa tarkastellaan markkinoiden yhtenevyyttä jaksolla 1985-1996. Analyysin kohteena ovat neljä pääpuutavaralajia eli mäntytukki, kuusitukki, mäntykuitu ja kuusikuitu. Näiden markkinoiden alueellista yhtenevyyttä *(market integration)* tutkitaan Johansenin yhteisintegroituvuusanalyysilla neljällä vuosien 1995–1996 hintasuositussopimusalueella.

Tulosten mukaan kaikki aikasarjat ovat epästationaarisia ja yhteisintegroituneita. Sarjojen välisten tasapainorelaatioiden perusteella markkinoiden alueellinen yhtenevyys näyttäisi pätevän vain mäntytukin osalta. Mäntytukilla markkinoiden valtakunnallisen yhtenevyyden taustalla lienee itsenäisten sahojen kilpailua lisäävä vaikutus. Kuusitukin markkinat eivät kuitenkaan osoittautuneet valtakunnallisiksi, vaikka itsenäisiä sahoja on myös kuusitukkimarkkinoilla. Tämä saattaa johtua siitä, että kuusen osuus puustosta pienenee pohjoista kohti mentäessä, mikä erilaistaa kuusitukin markkinoita mäntytukkia voimakkaammin.

Kunkin puutavaralajin kohdalla eri alueiden hinta-aikasarjojen välisiä vaikutussuhteita tutkittiin testaamalla yhteisintegroituvuusanalyysin puitteissa muuttujien heikkoa eksogeenisuutta. Järvi-Suomi on mäntytukilla ja kuusikuidulla ollut eksogeeninen, eli alue on ollut hintavaihteluiden lähde. Mänty- ja kuusikuidulla Etelä-Suomen hinnat ovat vaikuttaneet hintoihin muualla maassa. Hintamuutokset näillä runsaasti puuta käyttävillä alueilla ovat siis siirtyneet muualle Suomeen, mikä voi kuvastaa markkinoiden olevan pikemminkin kysyntä- kuin tarjontavetoiset. Käytännössä puutavaralajien markkinoiden erilaisuus ja alueellinen luonne korostavat esimerkiksi puutavaralajeittaisen ja alueellisen markkinainformaation merkitystä. Eri alueiden merkitys hintamuutosten lähteinä antaa myös hyödyllistä tietoa markkinoiden muutoksia ennakoitaessa.

Saatujen tulosten perusteella näyttää siltä, että oletus valtakunnallisista puumarkkinoista ei pitäisi koko tutkitulla ajanjaksolla paikkaansa. Valtakunnallisten markkinoiden oletus oli perusteltu erityisesti 1980-luvulla täsmällisten hintasuositussopimusten aikakaudella, mutta 1990-luvun voimakkaat muutokset sopimuskäytännössä voivat olla yhteydessä puumarkkinoiden rakennemuutoksiin. Periaatteessa yrityskohtaiset neuvottelut kantohintaodotuksista lieventävät markkinoiden alueellisuutta ja lisäävät kilpailua raakapuumarkkinoilla hajottamalla osapuolten neuvotteluvoimaa. Siksi sopimusjärjelmän muutosten yhteys alueellisiin kantohintoihin on kiinnostava jatkotutkimusaihe tälle työlle.

Avainsanat: *kantohinnat, aluemarkkinat, markkinoiden yhtenevyys, yhteisintegroituvuus*

1. Introduction

Finnish wood market is characterized by strong export demand-driven fluctuations in timber prices and quantities traded. Roundwood markets in Finland consist of a large number of relatively small sellers and fairly few large buyers. The 440 000 non-industrial private forest owners (NIPFs) own 62 per cent of forest land and produce about 80 per cent of the commercial roundwood entering markets (Kuuluvainen & Ovaskainen 1994). Recently mergers between forest industry companies have substantially increased buyer concentration in the wood market. Today the three largest companies account for 80 per cent of traded roundwood. These three companies were formed from 20 smaller companies that still existed as independent companies in 1986 (Uusivuori & Mykkänen 1996).

Voluntary nationwide agreements on recommending stumpage levels existed between unions of forest industry and forest owners during the felling seasons 1978/79 - 1990/91 in Finland. This negotiation system collapsed in 1991 and was inoperative for a period of three years. In 1994 a renewed contract was negotiated following the guidelines by the Office of Free Competition in Finland. In 1995 the voluntary price negotiations of recommended price levels were further separated from the national level into four different regions in Finland (see Appendix 1).

Previous econometric studies on the Finnish wood market have been based on 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 due to the existence of a voluntary stumpage price recommendation system between unions of forest industry and private forest owners during the 1980s. However, the 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 1985–95.* It is also of interest to analyze whether the assumption of full market integration in the Finnish wood market holds even though significant institutional and structural changes have taken place in the markets during the 1990s. In order to do this, the stochastic behaviour of stumpage prices during the period 1985–96 is studied by means of the multivariate cointegration analysis developed by Johansen

(1988, 1995).

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

The results of this study provide information on two aspects of the market integration and functioning of the Finnish roundwood market. First, we will study the long-run equilibrium relations between the prices in four geographic regions in Finland, i.e. southern, eastern, western and northern Finland. Second, because the major concentration of forest industry firms is in eastern Finland, price interdependencies between regions are compared with the direction of material flows in roundwood trade (see more Ylitalo *et al.* 1990 and Västilä & Peltola 1997).

2. Market integration

According to Ravallion (1986), measures of market integration can be viewed as basic data for understanding how specific markets work. Market analysis is incomplete unless we know how quickly price differentials between different areas reach equilibrium values (Silvapulle & Jayasuriya 1994). Thus our analysis provides new information on the dynamics of roundwood market adjustment[1].

The physical movement of goods from one place to another is a potential source of information on the geographic extent of a market. However, no volume of physical movement 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)[2]. Price has been considered as an ideal measure for the extent of a geographic market because the level of competition is reflected in market prices.

The concept of spatial market integration is based on the Takayama and Judge (1971) model of spatial competitive equilibrium of the neo-classical economy; if trade takes place between two markets, then competitive commodity arbitrage leads to an equilibrium in which prices differ only by inter-regional transportation costs. This assumes zero intra-regional transport 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). The concept is also denoted as "the law of one price" 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 of transportation costs, arbitrage between regions is not profitable. Prices in different regions will fluctuate independently of each other in response to localized changes in demand and supply conditions (Goodwin & Grennes 1994). Because

[1] However, some other researchers, e.g. Faminow & Benson (1990), state that market integration tests could be even interpreted as tests of alternative oligopoly price formation processes.

[2] In product range two products are in the same market, *i.e.* are close substitutes in production or 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.

transportation costs are usually either minor or stable and the data are not easily available, their influence is often ignored in empirical work (however see Baffes 1991).

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.

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 between two price series with 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 (see e.g. Goodwin & Scroeder (1991) on cattle markets, Alexander & Wyeth (1992) on Indonesian rice markets, and Bessler & Fuller (1992) on the 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 modelling. This method has been used for example by Silvapulle & Jayasuriya (1994) in studying rice market integration in Philippines.

There have been few econometric studies of the forest sector that deal with market integration. Uri and 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 in Jung & Doroodian (1994) and Hänninen (1996). Recently, Thorsen (1996) has studied the integration of timber markets in Scandinavia by testing the law of one price between different countries. As well, very few studies have utilized short-run, i.e. monthly or quarterly market data (see, however, Tilli & Uusivuori 1994 and Tilli 1997).

3. Methods of analysis

Cointegration is a statistical property of data that can describe long-run co-movement between economic time series (Engle and Granger 1987). Cointegrated time series share the property that there exists a common equilibrium level to which their fluctuations have a tendency to revert. Since co-integration assumes non-stationarity of the time series data used, tests for non-stationarity are necessary prior to testing for cointegration. The traditional approach for testing non-stationarity of time series has been to use Augmented-Dickey-Fuller unit-root tests (Dickey & Fuller 1979).

During the 1990s, Johansen's (Johansen 1988, 1995) multivariate cointegration method has been the main method in testing for cointegration. Testing is based on an unrestricted *p*-dimensional VAR model, which can be formulated in error-correction form as

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

where x_t is a $(p \times 1)$ vector of variables in the system (Johansen & Juselius 1990). The constant term (μ) is 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. Introducing 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. Likelihood ratio-test (a trace-test), derived by Johansen (1988), is used to test for rank, i.e. the number of stationary equilibrium vectors spanned by the cointegration space.

In testing for market integration with four different price agreement regions (p=4), we used first the cointegration rank test and then the linear restriction tests. In general, if there is cointegration between the price variables, 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 *p*th price.

In our case particularly, 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 in fact be a single national market. Alternatively, if the estimated rank (*r*) is less than *p–1* (i.e., 4–1=3), the degree of market integration is lower and the implication is that the geographical market structure can not be characterised as a single market.

In addition, using Johansen´s method it is possible to test for linear restrictions with χ2-distributed likelihood ratio tests (c.f. Johansen & Juselius 1992). Thus we can explicitly test whether coefficients for two individual prices in an estimated cointegrating vector are equal to each other in the long-run, i.e. (1, –1). With four regional prices in each of our four price systems, our H_0 hypothesis of full long-run market integration is the following restriction pattern on cointegrating vectors β:

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

where H is a design matrix giving the restrictions on the β matrix and φ is a (3 x 3) matrix. The likelihood ratio statistics are χ2(3) distributed.

A third phase of our analysis consists of testing for the relationships between regional prices. This can be done, for example by using linear restrictions in PcFiml (Doornik & Hendry 1994). In our case, we test for weak exogeneity of individual prices in each of the systems. A variable is called weakly exogenous if it does not adjust to deviations from any equilibrium relation in the short run, i.e. that the adjustment towards equilibrium takes place through changes in the other variables but the weakly exogenous one. Testing for weak exogeneity of prices with respect to long-run parameters allows us to draw conclusions concerning which prices are the driving stochastic trends in the Finnish roundwood market.

4. Empirical data and results

Time series data

In the empirical analysis we used monthly average regional stumpage prices for the following wood assortments: pine sawlogs, spruce sawlogs, pine pulpwood and spruce pulpwood.[3] It can be assumed that prices for different roundwood types contain information that would be lost by aggregating the data. Finland was divided into four separate regions by Forestry District Boards; i.e. southern, eastern, western and northern Finland (see Appendix 1). During the research period the respective shares of the regions in traded volumes have been on average 28, 46, 12 and 13 per cent. A more regionally disaggregated division, for example by all 19 Forestry District Boards, was not considered because it would have lead to a system of too high dimension for analytical purposes.

Series of monthly prices covering the period from October 1985 to March 1996 were used (T=126). Data was obtained from the on-line forestry statistics of the Finnish Forest Research Institute (METINFO). The nominal stumpage prices were deflated with the domestic wholesale price index, and logarithmic forms of the deflated series were used in the statistical analysis.

Wood transportation costs in Finland are non-negligible, since 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 part of the roundwood entering the market in Finland, about 70 per cent, is sold as stumpage. Due to this, wood prices in Finland are determined in the stumpage sector of the market. Transportation costs are also relatively constant over time compared to wood prices, and thus their omission, due to a lack of time series data, should not be considered a serious shortcoming of the analysis.

In Figure 1, regional stumpage prices are presented by four wood assortments. Similar business cycles are found to be present in all stumpage assortments. No significant price

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[3] Birch sawlogs and pulpwood were not studied, owing to the fact that their traded volumes have been very low especially in the Northern Finland and therefore there were a number of missing observations in the respective time series.

divergence can be visually detected from the graphs.

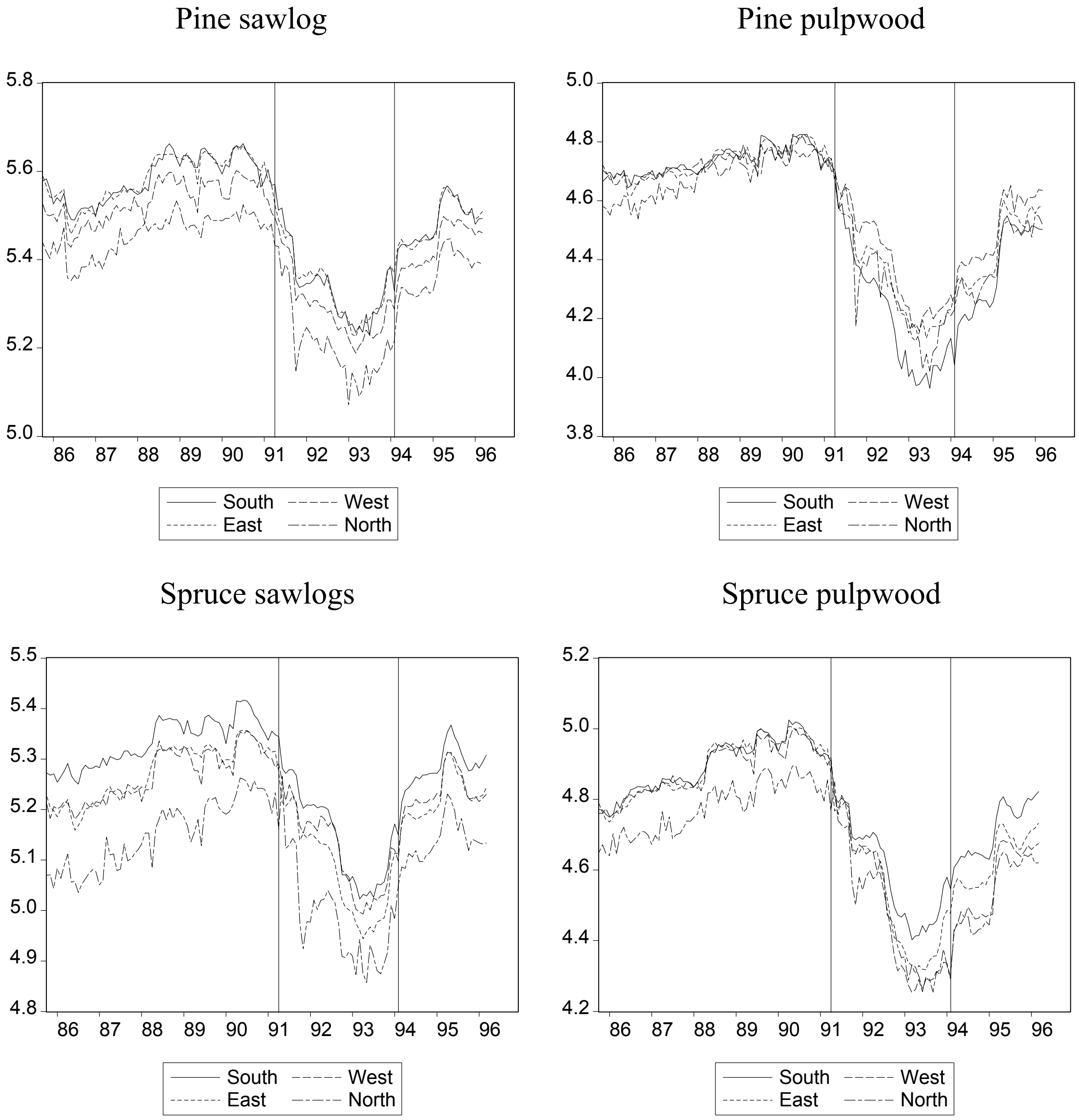

Figure 1. *Graphs of the regional stumpage prices (real prices in logarithms). First vertical line indicates the collapse of stumpage price recommendation in 1991, the second line indicates the new system in Spring 1994.*

Results of the market integration tests

We start statistical analyses by testing for the unit roots in individual time series for four stumpage assortments by four different regions. Augmented Dickey-Fuller (ADF) tests indicate that the levels of all sixteen price series were non-stationary, but the first differences of all prices are stationary (Table 1). Hence, it is possible to proceed with the cointegration analysis. The reported ADF-test statistics were obtained from a model including a constant, a trend and three lags, but it seems that the conclusions hold regardless of inclusion of trend and constant or of the number of lags used (from 1 to 6).

Table 1. ADF-test results for roundwood prices by regions in Finland.

Prices	ADF-test by[1)] Regional prices			
Levels	South	East	West	North
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*

1) Critical value for the ADF test is –4.03 at 5 % level.

Since the price series were non-stationary, we proceeded by testing for cointegration between them. Using Johansen's cointegration analysis, VAR models were formulated for each wood assortment. Thus we had four price systems, each including four prices. Using sequential decreases in the number of lags and diagnostic tests (Appendix 3), a three-lag VAR model ($p=4,\ k=3$) was a suitable statistical representation for removing residual autocorrelation in each model.

Degree of market integration was tested by estimating the rank of the four price systems using the Johansen procedure. The tests revealed that the hypothesis of full market integration in Table 2 was supported only in pine sawlog market (trace tests indicate $r= 3$). For spruce sawlogs and pine pulpwood, the indicated rank was 2. For spruce pulpwood, $r= 2$ was also accepted since the trace-test value was close to the critical value, indicating two cointegrating vectors.

Further, we tested explicitly, under $r=3$, for full market integration by using the linear restrictions shown in equation (2). For pine sawlogs, the likelihood ratio test for coefficients in cointegration vectors could be accepted, which is consistent with three statistically significant cointegration vectors (Table 2). By contrast, the null hypothesis of full market integration was rejected for the other assortments.

Table 2. Regional stumpage price system for each wood assortment (pine sawlogs, spruce sawlogs, pine pulpwood and spruce pulpwood).

	Cointegration rank test				Full market integration test
Ho:	$r = 0$	$r \leq 1$	$r \leq 2$	$r \leq 3$	Ho: r=3
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 %	47.2	29.7	15.4	3.8	
Spruce sawlogs					
Eigenvalues	0.26	0.14	0.08	0.02	26.4**
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	14.95**
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	7.94*
Trace test value	55.9**	29.4	10.8	1.7	
95 %	47.2	29.7	15.4	3.8	

Note: ** indicates significance at 1 % level and * at 5 % level. Market integration test (see equation 2) is done under r=3, with the 5 % critical value of $\chi2(3)$=7.82.

To check the robustness of full market integration test, we estimated cointegration vectors also using two sub-samples of data, 1985–91:02 and 1991:03–96 (not reported). This division coincides with the collapse of the collective national level stumpage price negotiation system in Finland in March 1991. Bearing in mind the loss in reliability of cointegration tests as weakened by the shortness of the partial data series used, our results indicated that for pine sawlogs the full market integration hypothesis was valid using both data periods. Also for spruce sawlogs, the results were robust with respect to estimation period, indicating at 1 % 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. According to these changes, market integration in the markets of the two pulpwood assortments appears to have slightly diminished in the early 1990s.

Changes in the regional pulpwood markets can also be depicted looking at the development in relative prices between regions in Figure 2. Relatively constant pine pulpwood price ratio between eastern Finland and other regions levelled off in 1991. In the spruce pulpwood market, relative prices also changed increasing the regional relative price differences. These sudden changes coincide with the collapse of the stumpage price negotiation system. When the new price negotiations initiated in 1994, relative prices slightly converged to each other again.

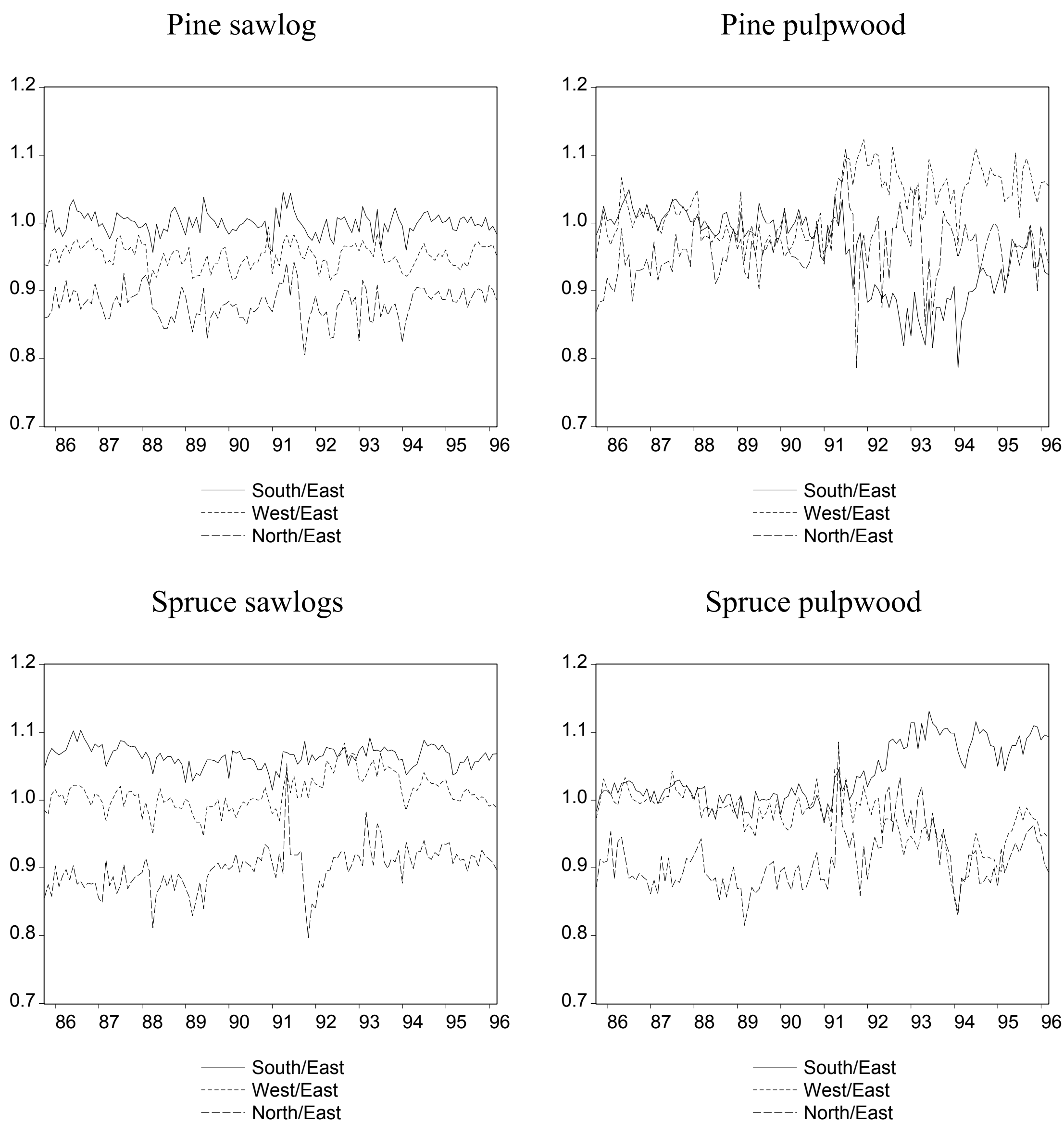

Figure 2. *Relative stumpage price development with respect to prices in eastern Finland.*

Interrelationships between regional price series

After testing for full stumpage market integration, we proceeded by testing for weak exogeneity of individual price variables for each geographic region (Table 3). In the pine sawlog system, the test statistics for the null hypothesis of weak exogeneity (H_0: α_i =0, i.e., no adjustment effect with respect to the other prices) revealed that stumpage price for eastern Finland was weakly exogenous to prices in the other regions. This result suggests that eastern Finland has been the origin of stochastic trends in the market for pine sawlogs.

Table 3. Weak exogeneity tests under estimated cointegration rank *r*.

Ho: αi =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**

* (**) indicates rejection of null hypothesis at 5 % (1 %) level. For critical values, see Table 2.

For spruce sawlogs, the price for northern Finland was found to be exogenous and the second relationship originating from eastern Finland was also close to critical values. In the pine pulpwood market, prices in southern and western Finland were found to be weakly exogenous, while in spruce pulpwood market prices from southern and eastern Finland were found to be weakly exogenous with respect to other prices.

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 other markets, the estimated cointegration rank (*r* = 2) was, roughly speaking, consistent with two common trends and two exogenous variables in the market.

The revealed pattern in exogenous prices was consistent with the relative importance of regional markets regarding wood consumption. In particular, the analysis reflected the role of eastern Finland, which is the dominant area of the market and main user and importer of industrial roundwood (c.f. Ylitalo et al. 1990, see Appendix 2 on the location of wood processing industry): Stumpage prices in eastern Finland were a significant source of price fluctuations in three out of four wood assortments.

5. Summary and discussion

In this study we analysed market integration between four geographic regions in Finland by four separate wood assortments 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 the rank test indicates the degree of market integration.

In general, our empirical results using Johansen's (1995) multivariate cointegration tests indicate that the degree of roundwood market integration in Finland varies between wood assortments. This result shows the advantages of using highly disaggregated empirical price data, i.e. by assortments, regions and time, for analysing roundwood markets as compared with the more commonly used approach.

More precisely, the null hypothesis of full long-run market integration and one common stochastic trend could be accepted in the empirical analysis only for pine sawlogs. For spruce sawlogs and two pulpwood assortments (pine and spruce), the cointegration rank test indicated two separate cointegrating vectors and two common trends. Hence, it seems that the stumpage markets of pine sawlogs are nationwide whereas the markets of other assortments are geographically disaggregated at least to some degree. Furthermore, by using cointegration tests by two sub-samples of data, market integration test indicated diminishing integration for both pulpwood assortments with the break-up in the early 1990s. However, given the potentially low power of the tests used (Johansen & Juselius 1990), these results should not be taken as strong evidence against integration of these markets.

The analysis of interrelationships between regional time series revealed that eastern Finland was the driving area of price changes. In pine and spruce pulpwood prices, southern Finland was the driving region. Southern Finland was accompanied by western Finland in pine pulpwood and eastern Finland in spruce pulpwood. For spruce sawlogs, the results from weak exogeneity tests indicated northern Finland as the main origin of the fluctuations, accompanied by eastern Finland. A clear explanation for the strong role of northern Finland in spruce sawlog market result is difficult to provide, but it may be due to the low volume of spruce sawlogs trade in northern Finland. The low volume increases price volatility, and this may be seen in our results.

Our general conclusion based on weak exogeneity test results is that stumpage prices in the Finnish roundwood market are driven by factors related to wood demand rather than supply. This conclusion is based on the fact that the largest wood using and also importing regions (by volumes) seem to determine the price changes in the other regions but not vice-versa. Hence, the physical roundwood flows are directed to eastern and southern Finland from other regions. By contrast, the price changes are initiated in eastern and southern Finland, and then transferred to other regions. In particular, the results emphasise the strong role of eastern Finland as the driving area of price changes in the roundwood market.

Statistical evidence for the full market integration hypothesis in pine sawlogs may be connected with the slightly lower degree of buyer concentration in pine sawlog market than in the other wood assortments (see Västilä & Peltola 1997). Thus, the existence of independent sawmills in Finland probably enhance competition in the roundwood market. The independent mills are operating actively also in the spruce sawlog market. However, in the spruce market the geographic conditions differ from the relatively homogeneous pine market; in northern Finland the share of spruce resources is significantly lower than in southern Finland.

Rejection of full long-run market integration in three out of four wood assortments emphasises the need for further research in this field. Reasons for this could be sought, for example, in recent changes in the stumpage price negotiation system, which coincides with divergence in relative prices. Alternatively, changes could be related to imperfect competition or inefficiency of trade between the regions. However, these questions are out of scope of this study, but underline the need for further analysis in regional price determination than what was possible here. In 1997, negotiations on stumpage price expectations started to take place between forest owners, i.e., sellers of wood and individual forest industry companies. This change is likely to decrease the role of regional factors in the market and enhance competition by splitting the bargaining power in negotiations. Therefore the effects of this structural change on relative regional stumpage prices remain as an interesting possibility to extend this work.

The results of our work also serve practical decision making. For example, the evidence of both geographically and assortment specific roundwood markets provides strong reasons to maintain and develop the present market information services on roundwood markets. In addition, knowledge about the existence of regional instead of national roundwood markets may be helpful for the market actors. As important is to realise the strong role of eastern and southern Finland as the driving areas of price changes when anticipating the development of roundwood price development.

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References:

Alexander, C. & Wyeth, J. 1994. Cointegration and market integration: An application to the Indonesian rice market. The Journal of Development Studies. Vol. 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. Vol. 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 University Press. 320 p.

Bessler, D. & Fuller, S. 1992. Cointegration between U.S. wheat markets. The Journal of Regional Science. Vol. 33: 481–501.

Blank, S. & Schmiesing, B. 1988. Modelling of agricultural markets and prices using causality and path analysis. North Central Journal of Agricultural Economics. Vol. 10:35–48.

Dickey, D. & Fuller, W.A. 1979. Distribution of the estimators for autoregressive time series with a unit root. Journal of American Statistical Association. Vol. 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, London. 436 p. ISBN 1-850-32113-2.

Engle, R. & Granger, C.W.J. 1987. Cointegration and error-correction: Representation, estimation and testing. Econometrica, Vol. 55: 251–276.

Faminow, M. & Benson, B. 1990. Integration of spatial markets. American Journal of Agricultural Economics. Vol. 72: 49–62.

Goodwin, B. & Schroeder, B. 1991. Cointegration tests and spatial price linkages in regional cattle markets. American Journal of Agricultural Economics. Vol. 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. Vol. 13: 107–124.

Hetemäki, L. & Kuuluvainen, J. 1992. Incorporating data and theory in roundwood supply and demand estimation. American Journal of Agricultural Economics. Vol. 74: 1010–1018.

Hänninen, R. 1996. The law of one price in United Kingdom soft sawnwood imports – a cointegration approach. Forthcoming in Forest Science. 26 p.

Johansen, S. 1988. Statistical analysis of cointegration vectors. Journal of Economic Dynamics and control. Vol. 12: 231–254.

Johansen, S. 1995. Likelihood based inference in cointegrated vector autoregressive models. Oxford University Press. ISBN 0–19–877450–8. 267 p.

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. Vol. 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. Vol. 53: 211–244.

Jung, C. & Doroodian, K. 1994. The law of one price for U.S. softwood lumber: A multivariate cointegration test. Forest Science. Vol. 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. Vol. 1: 191–201.

Kuuluvainen, J. & Ovaskainen, V. 1994. Yksityismetsänomistajien puunmyynteihin vaikuttavat tekijät. Metsäntutkimuslaitoksen tiedonantoja 484. (Factors affecting the roundwood sales of private forest owners. Finnish Forest research Institute. Research Notes

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. Vol. 66: 481–487.

Ravallion, M. 1986. Testing market integration. American Journal of Agricultural Economics. Vol. 68: 102–109.

Silvapulle, P. & Jayasuriya, S. 1994. Testing for Philippines rice market integration: A multiple cointegration approach. Journal of Agricultural Economics. Vol. 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. Vol. 73: 568–580.

Stigler, G. & Sherwin, R. 1985. The extent of the market. Journal of Law & Economics. Vol. XXVIII:555–585.

Takayama, T. & Judge, G. 1971. Spatial and temporal price and allocation models. Amsterdam. North-Holland Publishing Co.

Thorsen, B. 1996. Common stochastic trends and the law of one price in the Nordic timber markets. Paper presented at the Workshop on stochastic decision analysis in forest management. 5–8.8.1996, Eldruppgård, Denmark. 23 p.

Uri, N. & Boyd, R. 1990. Considerations on modelling the market for softwood lumber in the United States. Forest Science. Vol. 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. 72 p.

Tilli, T. 1997. Metsäpääoman tuotoksen realisointiin liittyvö riski. Puun ennustamaton hintavaihtelu riskin mittarina Suomessa vuosina 1985-91 ja 1991-93. The risk of selling annual growth - Non-predictable price variation as an indicator of the risk in Finland during the years 1985-1991 and 1991-1993. Pellervo Economicc Research Institute. Reports and Discussion Papers No 148. 78 p. + Appendixes. (in Finnish)

Tilli, T. & Uusivuori, J. 1994. Puun hintavaihtelut Suomessa 1985-91 ja 1991-93. English summary: Short-Term Timber price Variations in Finland during 1985-91 and 1991-93. Pellervo Economic Research Institute. Reports and Discussion Papers No 132. 43 p. + Appendixes. ISBN 951-8950-46-6.

Ylitalo, E., Mäki-Simola, E. & Turunen, J. 1990. Markkinapuun alueittaiset hankintamäärät ja kulkuvirrat vuonna 1988. (Procurement and trade flows of roundwood by regions in 1988.) Folia Forestalia 758. 51 p

Västilä, S. & Peltola, A. 1997. Puun kulkuvirrat ja puun hankinnan keskittyminen 1994. Metsäntutkimuslaitoksen tiedonantoja 638. (Physical trade flows of roundwood and concentration of roundwood procurement in 1994. Finnish Forest Research Institute. Research Notes 638.) 21 p. + Appendixes. ISBN 951–40–1564–9. (in Finnish)

Total of 33 references.

Appendix 1. **Regions for negotiations of recommending roundwood price levels during 1995-1996.**

Appendix 2. **Locations of the Finnish forest industry processing plants in 1994.** (see Västilä & Peltola 1997)

Appendix 3. 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	Tests for residuals and standard errors			
	Autocorrelation [a]	Heteroskedasticity [b]	Normality [c]	Standard errors
	$F_{AR}(7,103)$	$F_{ARCH}(7,96)$	$\chi^2(2)$	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 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 4th order autoregressive conditional heteroskedasticity. [c] Normality of the residuals was tested with the Doornik-Hansen test (Doornik and Hendry 1994). For further detail and test references, see Doornik and Hendry (1994).