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Econometric models on the Finnish roundwood market

Anne Toppinen

HELSINGIN TUTKIMUSKESKUS – HELSINKI RESEARCH CENTRE

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Academic dissertation

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ABSTRACT

This thesis consists of this summary and five self-contained studies analyzing the short-term market behavior of the Finnish roundwood market. Motivation for the analysis is given by structural changes in the market environment during the 1980s and 1990s and methodological improvements in time series econometrics. The concept of cointegration between time series is emphasized in model construction. In contrast to most previous roundwood market studies, competitive features of the market are also examined. Annual data for 1960–94 and monthly data for 1985–97 at the aggregate market level and at the regional level are used in the analyses. Empirical results indicate that models assuming competitive markets were statistically well-suited for modeling price and quantity determination in the Finnish wood market in many cases. The collective stumpage price recommendation system was, however, found to have had a significant positive effect on both the pulpwood demand and on the supply of pulpwood from the nonindustrial private forest owners (NIPFs). The law of one price between the four major geographic regions in Finland was accepted for the case of pine sawlogs only, while results indicate that the importance of regional supply and demand factors has increased in the pine and spruce pulpwood markets during the 1990s. In the period 1985–97, stumpage price was found to have had a positive effect on sawlog supply both in the short and long-run, while only a long-run price effect was significant for sawlog demand. Results of this study can be used in specifying short-run models for forecasting the price and quantity fluctuations on Finnish roundwood markets.

Keywords: roundwood market, stumpage prices, pulpwood, sawlogs, demand, supply, competition, market integration, cointegration analysis, short-term forecasting

ABSTRAKTI

Väitöskirja koostuu yhteenvedosta ja viidestä artikkelista, joissa analysoidaan Suomen raakapuumarkkinoiden lyhyen aikavälin vaihteluita. Tutkimuksen taustalla ovat markkinaympäristössä tapahtuneet muutokset 1980- ja 1990-luvuilla. Lisäksi työssä hyödynnetään menetelmällistä kehitystä aikasarjaekonometriassa, erityisesti muuttujien välisen yhteisintegroituvuuvuuden mallintamisessa. Useimmista Suomen puumarkkinoita käsitelleistä tutkimuksista poiketen työssä selvitetään myös markkinoiden kilpailevuutta. Aineistona ovat koko markkinoiden tasoiset aikasarjat jaksolta 1960–94 sekä kuukausittaiset koko maan sekä neljän suuralueen tasoiset aikasarjat jaksolta 1985–97. Empiiriset tulokset osoittavat kilpailevien markkinoiden mallin soveltuvan useissa tapauksissa verrattain hyvin puumarkkinoiden kuvaukseen. Kuitupuumarkkinoilla havaittiin kuitenkin keskitettyjen hintasuositussopimusten vaikuttaneen yksityismetsien puun tarjontaa ja teollisuuden kysyntää lisäävästi. Vain mäntytukin markkinoilla neljän suuralueen välinen yhden hinnan laki jäi voimaan jaksolla 1985–96, kun taas mänty- ja kuusikuitupuulla alueellisten kysyntä- ja tarjontatekijöiden merkityksen havaittiin kasvaneen 1990-luvulla. Sahatukin kantohinnalla oli tarjontaa lisäävä vaikutus sekä lyhyellä että pitkällä aikavälillä kun taas sahatukin kysyntään hinnalla oli merkitsevä vaikutus vain pitkällä aikavälillä. Tutkimustuloksia voidaan hyödyntää Suomen puumarkkinoiden toimintaa kuvaavien lyhyen aikavälin ennustemallien kehittämisessä.

Avainsanat: raakapuumarkkinat, kantohinta, kuitupuu, tukkipuu, kysyntä, tarjonta, kilpailu, markkinoiden yhtenevyys, yhteisintegroituvuus, lyhyen aikavälin ennusteet

To my daughter Laura

Preface

The present study has been carried out in the project 'Short-term forecasting system of the Finnish forest sector' at the Finnish Forest Research Institute (Metla), led by Jari Kuuluvainen (1994–96) and Lauri Hetemäki (1996-98). I wish to thank Metla for providing me excellent working conditions and all my colleagues for friendly and inspiring working atmosphere during these five years. The research has been mainly financed by the Academy of Finland, Research Council for the Environment and Natural Resources. Research grants from Metsämiesten Säätiö and Suomen Metsätieteellinen Seura are also gratefully acknowledged.

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Finally, I wish to thank all my family and friends for their continuous support, especially my parents Kaisu and Matti Halko, who have as NIPF owners provided a real life interest to studying timber markets. During my whole research career, support and understanding from my husband Sami has been very important, as was his example on how to proceed with doctoral studies.

Parhaimmat kiitokset teille kaikille!

Helsinki, 7.9.1998

Anne Toppinen

CONTENTS:

LIST OF ORIGINAL PAPERS

In addition to this summarizing report, the dissertation includes the following studies, which are referred to by roman numerals in the text as follows:

I. Toppinen, A. & Kuuluvainen, J. 1997. Structural changes in sawlog and pulpwood markets in Finland. Scandinavian Journal of Forest Research. Vol 12, 382–389.

II. Toppinen, A. 1997. Testing for Granger-causality in the Finnish roundwood market. Silva Fennica. Vol 31, 225–232.

III. Ronnila, M. & Toppinen, A. 1998. Testing for oligopsony power in the Finnish wood market. Manuscript. 21 p. (submitted)

IV. Toppinen, A. & Toivonen, R. 1998. Roundwood market integration in Finland: a multivariate cointegration analysis. 31 p. Journal of Forest Economics. Vol 4. (in press)

V. Toppinen, A. 1998. Incorporating cointegration relations in a short-run model of the Finnish sawlog market. Canadian Journal of Forest Research. Vol 28, 291–298.

The articles I, II and V are reprinted with permission.

1 INTRODUCTION

The forest sector, including forest industry and forestry, plays a significant role in the Finnish economy. Although the share of forest industry in total Finnish exports of goods has declined during the past decades it still constitutes about one third of export earnings. At the regional level, forestry and small scale wood-working industry have special importance in bringing stumpage price earnings and working opportunities to rural areas in Finland.

Depending on the degree of competition in the market, possible market structures vary between perfect competition and monopoly (or monopsony) with a single seller (or, for monopsony, buyer) of a product in the market. In between, there are various possible market structures, where strategic interaction between agents in the market is possible (see e.g. Varian 1993, Tirole 1988). An additional alternative for the roundwood market structure, the bargaining model, arises from the literature on trade union behaviour between the associations of forest industry and forest owners. As will be shown in Chapter 3, all of these models receive some indication from actual roundwood market characteristics in Finland. Thus, empirical modelling of the market is needed in order to distinguish between various alternative market structures.

A more detailed description of the structure and institutional arrangements in the Finnish roundwood market is given in Chapter 3, and it suffices to note here that there have been recent changes in the Finnish economy, and in the forest sector in particular, that emphasize the need for reformulating econometric models for the Finnish roundwood market. Finland undertook capital market liberalization in the mid 1980s, which may have affected the timber supply behaviour of nonindustrial private forest owners (NIPFs), (see, e.g., Pajuoja 1995 on empirical evidence of the effects of credit rationing on the harvesting behaviour of bookkeeping farms)[1]. Corporate mergers and acquisitions in the late 1980s and 1990s have increased buyer concentration in the Finnish market, which may have affected stumpage price determination. Finally, the renewal of competition legislation in Finland in 1992 has changed the contents

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1 Also the ownership structure of NIPF owners has changed during the past decades (see Ovaskainen and Kuuluvainen 1994, as well as Ripatti 1996), but micro-level studies on NIPF timber-selling behaviour have not yet revealed any specific supply shifts due different roles and motives of forest owners (e.g. Kuuluvainen et al. 1996).

and roles of stumpage price agreements considerably, and it is not clear how this has affected on the market. Because older studies were not designed for the analysis of the most of the above-mentioned features, there remains a need for careful modelling of the factors determining the equilibrium of the Finnish roundwood market in the 1990s.

The main purpose of this study is to gain empirical insights into the functioning of the Finnish timber markets using the cointegration analysis advocated by Johansen (1988, 1995). Competitive conditions in the market are evaluated by studying the effects of the stumpage price recommendation system on the Finnish sawlog and pulpwood markets, as well as by testing for imperfect competition in the wood input markets of the Finnish pulp industry. Also, while previous studies have largely neglected to test the forecasting properties of their models, this study especially emphasizes such analysis.

This dissertation consists of five self-contained studies focusing on different aspects of short-term stumpage price and wood quantity determination in a small open-economy context.[2] The analysis is carried out in a partial equilibrium framework, and thus all other sectors in the economy are considered exogenous to forestry. The research objectives of the five included studies can be summarized as follows:

Study I:

- to extend the competitive timber market models presented in Hetemäki and Kuuluvainen (1992) to analyse short-term behaviour in both sawlog and pulpwood markets using statistically well-defined specifications
- to test whether the stumpage price agreement system has had an effect on the timber market

Study II:

- to test for causal interrelationships between stumpage prices, wood quantities and export prices of forest industry products in Finland

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[2] See however e.g. Hänninen (1986) or Laaksonen et al. (1997) on the use models of imperfect competition in modelling the Finnish exports of forest products.

Study III:

- to test whether the Finnish pulp industry has oligopsony power in its wood input markets

Study IV:

- to test the law of one price (i.e. the degree of market integration) between four regional timber markets in Finland by four wood assortments
- to study causal interrelationships between stumpage prices in different regions

Study V:

- to examine the supply and demand determinants in the Finnish sawlog market both in the short- and long-run[3]
- to evaluate the short-term forecasting properties of the market model

Understanding how the roundwood market functions is essential information, for example, in the design of optimal forest policies, so that if there are significant distortions from a competitive market equilibrium, public intervention is justified to correct them. The results of this study are of interest for both individual market agents and as background information for policy-makers, in both the forest sector and the whole Finnish economy. For example, the elasticities estimated in this study can be used to evaluate how sensitive the quantities demanded and supplied are to changes in (endogenous) stumpage prices or to changes in any of the exogenous variables. Information about relevant market structure is also important when specifying the models for forecasting the price and quantity fluctuations in a cyclical market. In this respect, the results also aid practical short-term forecasting work for the Finnish forest sector.

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[3] The models in this study can be characterized as short-run models, and whenever the discussion concerns long-run effects, e.g., regarding error-correction models (as in studies IV and V), the term long-run refers to economic equilibrium.

The outline of this Summary is as follows: Theoretical models for roundwood markets are briefly discussed in Chapter 2 which includes a review of previous econometric studies. The main characteristics of the Finnish roundwood market are reviewed in Chapter 3. Empirical methodology and data is described in Chapter 4. Chapter 5 includes a short summary and discussion of each individual study. Finally, Chapter 6 contains concluding remarks and points out opportunities for further research.

2 PREVIOUS MODELS ON THE ROUNDWOOD MARKET

2.1 Theoretical models

In a competitive roundwood market, equilibrium timber price is determined by equating the aggregate demand for, and supply of, wood.[4] On the demand side, a representative profit-maximizing forest industry enterprise sells its outputs in competitive world markets. It produces output y using two inputs, q (wood) and x (representing other inputs than wood), which both have given prices c and z, respectively. Ignoring raw material inventory decisions and uncertainty, the profit maximization problem of forest industry is formulated using the profit function:

$$(1) \qquad \pi^*(p,c,z) = \max_{q,x} \pi = pf(q,x) - cq - zx.$$

In a competitive wood market, the quantity of wood bought is determined by equating the factor price and the perceived marginal revenue product of the factor. Using Hotelling's lemma, partial differentiation of the profit function with respect to product price yields the product supply function, while partial differentiation of the indirect profit function with respect to wood price yields the negative of the demand function for the wood input (see e.g. Varian 1993):

$$(2) \qquad \frac{\partial \pi^*}{\partial p} = y(p,c,z)$$

$$(3) \qquad \frac{\partial \pi^*}{\partial c} = -q(p,c,z)$$

Consequently, the roundwood demand function to be estimated can be expressed as

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4 Perfect competition is characterised by homogenous products, perfect information, price taking behaviour, no externalities or transaction costs and no barriers to entry or exit from the market. Some economists also assume that a perfectly competitive market has a large number of buyers and sellers, but, basically, the assumptions listed here are sufficient to guarantee perfect competition (e.g., Carlton and Perloff 1994).

$$(4) \qquad q_t^d = q(\underset{+}{p_t}, \underset{-}{c_t}, \underset{+/-}{z_t}),$$

where q_t^d is demand for roundwood in period t, p is the price of final products, c is stumpage price and z represents the prices of other inputs. The effects of other inputs on wood demand cannot be revealed a priori, because they can be either substitutes or complements in production with respect to raw material input. Previous studies of factor demand in forest industry have either indicated that roundwood and labour are substitutes (e.g., Newman 1987, Hetemäki and Kuuluvainen 1992) or complements (e.g. Merrifield and Haynes 1983, Sherif 1983, Bergman and Brännlund 1995) in production. The relation between roundwood and capital has been found to be complementary in some studies (e.g., Newman 1987, Hetemäki and Kuuluvainen 1992) while in other studies these factors have been found to be technical substitutes in production (e.g., Merrifield and Haynes 1983, Hetemäki 1990).

Theoretical models of wood supply are usually classified into models of long-run and short-run timber supply (see e.g. Binkley 1987). The problem of optimal rotation period is essential in forest management and in the modelling of the long-run timber supply. According to the basic Faustmann model, the maximization of the net present value of a forest stand is accomplished by cutting the stand when its relative value growth equals the opportunity cost, i.e. the interest on the standing stock and forest land (e.g. Johansson and Löfgren 1985). As a practical tool for short-term market forecasting, however, the linear forest model composed of a set of stands managed under Faustmann model is limited because it does not recognize the significant fluctuations in harvesting levels and prices (e.g., Binkley 1987). Recently, characteristics of specific forest owner have been incorporated into an optimal rotation model which also includes different forest age classes and allows for short-term price fluctuations (Tahvonen 1997). This owner-specific model has been succesfully applied to empirical micro data on Finnish NIPF owners (Kuuluvainen and Tahvonen 1997).

Regarding timber supply, there have been a number of applications of a two-period Fisherian consumption-savings model on the short-run timber supply analysis in the presence of market imperfections during the 1980s and 1990s (for the analysis on the role of silvicultural efforts, forest taxation, non-timber values and price and interest rate uncertainty on timber supply see e.g., Koskela 1989a,b, Ovaskainen 1992, and Ollikainen 1996). In a two-period model, the decision problem of a forest owner is how much to cut today and how much leave to be cut in the future. In a two-period framework, the optimal decision on timber supply and consumption depends on the state of capital market or on other market imperfections (Koskela 1989b). In perfect capital markets, consumption and production decisions are separable and the income from the optimal intertemporal harvest can be allocated for optimal consumption via the capital market. Supply of roundwood in period t depends on stumpage price in period t and $t+1$, the interest rate and the initial timber stock:

(5) $$q_t^s = q(\underset{+}{c_t}, \underset{-}{c_{t+1}}, \underset{+}{r_t}, \underset{+}{v_t}),$$

where q_t^s is supply of roundwood, c is the current and expected stumpage price, r is the short-term market interest rate and v is the initial timber stock.

If, however, the forest owner faces a binding borrowing constraint, timber supply decisions also become dependent on forest owner specific preferences, as consumption and harvesting decisions must be made simultaneously (e.g. Kuuluvainen 1990). Ignoring the effect of subjective rate of time preference of an individual forest owner when using aggregate time series data, timber supply depends on present and expected (second period) stumpage prices, the expected interest rate, the initial growing stock and the present and expected non–stumpage income of the forest owner:

(6) $$q_t^s = q(\underset{+/-}{c_t}, \underset{-/+}{c_{t+1}}, \underset{-}{m_t}, \underset{+}{m_{t+1}}, \underset{-}{r_{t+1}}, \underset{+}{v_t}),$$

where q_t^s is quantity of wood supplied, c is stumpage price in the two periods, m is nonforestry income, r is the market interest rate and v is the timber stock at the beginning of each observation period (e.g., felling year).

One alternative approach for modelling timber price determination is to assume a monopsony roundwood market. In a monopsony there is only one buyer of wood with market power over the price of wood. When excluding other inputs than wood for simplicity, the firm's problem is to maximize profits π as (see e.g. Johansson and Löfgren 1985, Ch. 8)

(7) $$\pi = py(q) - c(q)q,$$

where quantity demanded, q, is equal to market supply of wood. Thus, the firm realizes that its input demand decision affects the price of wood. The firm's optimal decision is then determined by equating the marginal product value of an input to the perceived marginal cost of an input as

(8) $$p\frac{\partial y}{\partial q} = c(1+\frac{1}{\varepsilon}),$$

where ε is the roundwood supply elasticity, $\varepsilon = (\partial q/\partial c)(c/q)$. In a monopsony with a finitely elastic wood supply, the roundwood price is lower than the competitive market price. The relative price distortion is inversely proportional to the elasticity of wood supply; the less elastic roundwood supply is, the higher the relative price distortion caused by the monopsony is. If there are only few large firms in the industry buying roundwood, and they recognize their strategic interdependence, the market may be characterized as an oligopsony. Assuming that all firms face identical marginal prices, the optimality condition in an oligopsony can be written as

(9) $$p\frac{\partial y}{\partial q} = c(1+\theta\gamma),$$

where θ is the conjectural variations elasticity and γ is the inverse supply elasticity of wood, i.e. $\gamma = 1/\varepsilon$ (see study III for a more comprehensive description of this type of market model).

A third alternative market structure, which is not considered explicitly in this study, is the case in which stumpage prices (or both prices and quantities) are determined in negotiations between representatives of forest industry and an association of forest owners. In a price-bargaining model, the wood price is subject to negotiations and the quantity traded is then determined either from the wood supply or demand curve; if the negotiated price is below the competitive market price, the observed wood price is on the supply curve, since it is the willingness of wood sellers that determines the quantity. In contrast, if the negotiated price is above the competitive level, the price is on the demand curve. In an efficient bargaining model (see e.g. Risku 1997), both the wood price and quantity are subject to negotiations, and neither demand nor supply curve can be identified since the observed prices and quantities are off both the curves.

Following the price bargain model set forth in Koskela and Ollikainen (1998b), the forest owner association's maximization problem over timber revenues can be written as

$$(10) \qquad V = (p - e(r,m))x^d,$$

where p is the timber price, e is the reservation timber price which forest owners require in order to sell timber (as a function of interest rate r and forest amenity values m as reflected by timber stock) and x^d is timber demand. On the demand side, the normal profit maximization problem of forest industry applies; they maximize $\pi = qy - px - rk$, where q is the inverse aggregate demand function, y is the production function ($y = f(x,k)$), and p and r are the input prices of wood x and capital k, respectively. The Nash bargaining maximand can be written as

$$(11) \qquad \Omega = V^{\beta}\pi^{1-\beta}$$

with β representing the bargaining power of the forest owners' association. The first order condition with respect to timber price is multiplied by p to get

$$(12) \qquad \Omega_p = 0 \Leftrightarrow \beta\frac{V_p p}{V} + (1-\beta)\frac{\pi_p p}{\pi} = 0,$$

with $\pi_p = -y(c_p - q'y_p) < 0$ so that $V_p = \frac{x}{p}\left[p(1-\eta) + e\eta\right] > 0$, where η is the price elasticity of timber demand and c, $c = c(y,p,r)$ is the cost function of the industry. Thus, timber price is set so that the price elasticity of the forest owners' association's utility is equal to the negative price elasticity of forest industry's profits weighted by the relative bargaining strength of both parties. If the bargaining power of the forest owners' association is comprehensive so that it has all the bargaining power ($\beta = 1$), timber price is set monopolistically (e.g. Koskela and Ollikainen 1998a).

2.2 Empirical studies

Empirical modelling of the demand for, and supply of, roundwood has generally been an important research topic in forest economics. The timber markets in Finland have many similarities to markets in Sweden and in some parts of North America; therefore, relevant studies on roundwood markets in these countries are reviewed in the following section and then compared with Finnish studies.[5]

The earliest econometric studies of roundwood markets in the United States (e.g. Leuschner 1973, Adams and Blackwell 1973, Robinson 1974 and Haynes 1977) typically used a derived demand linkage between markets of roundwood and of forest products. Regional differences in wood markets are great in the United States, and therefore special emphasis has been put on economic modelling of regional sub-markets. A seminal paper in spatial equilibrium market models in forest economics is Adams and Haynes (1980). Later, price and quantity determination in pulpwood and sawlog markets in the Southern states have been considered in Newman (1987) and for the Texan pulpwood market in Carter (1992). In contrast to the above mentioned studies, Murray (1995) studied imperfect competition in the U.S. markets for pulpwood and sawlogs using the conjectural variations approach. He concluded that the degree of oligopsony power was higher in the pulpwood market than in the sawlog market, though both markets were found to perform closer to perfect competition than to monopsony. In Bernstein (1992), the price taking behaviour in the Canadian sawnwood and paper markets and in the input markets for pulp and wood was tested by taking the capital adjustment costs in the industries into account, but the results did not justify the rejection of the competitive behaviour hypothesis in any of the markets.

5 This review concerns only empirical studies which employ time series data. In addition, a large number of empirical econometric studies of timber supply employing cross-section and pooled cross-section data exist, but are not considered here (for Finland see e.g., Kuuluvainen 1989, Kuuluvainen et al. 1996 and Pajuoja 1995).

An empirical model of the Swedish roundwood market consisting of a competitive sawlog market model and a monopsony market model for pulpwood is considered by Johansson and Löfgren (1985) (see also Brännlund et al. 1985). In a later study by Brännlund (1988), an equilibrium model of the sawtimber market was tested against a disequilibrium model. The pulpwood and sawlog markets were modelled simultaneously in order to measure the welfare losses for the sector caused by the monopsonistic pulpwood market. According to the results, underpriced pulpwood effected the relative sizes of pulpwood and sawtimber markets, but, in general, the welfare losses to society were found to be small (Brännlund 1988, 1989).

In a study by Hultkranz and Aronsson (1989), a forest inventory of mature trees ready for the final felling and lagged capital cost variables were found to be significant factors in explaining aggregate wood supply in Sweden. Bergman (1992) disaggregated the Swedish wood market according to different supply sources, i.e., private industrial, nonindustrial (NIPF) and public forests. Forest inventory was found to be the major determinant in wood supply from the respective cutting classes, while the own-price effects were statistically insignificant. In Bergman and Brännlund (1995), the oligopsonistic market structure was tested using data for the Swedish pulpwood market. The empirical results indicated a noncompetitive pulpwood market assuming that the market power of the industry was varying over time.

Econometric modelling of price determination in the Finnish roundwood markets was very scarce before the 1980s.[6] Korpinen (1980) modelled sawlog fellings in Finland for the period 1950–78.[7] Kuuluvainen (1986) studied the Finnish sawlog demand as a derived stock demand using raw material stocks in the sawmill industry to anticipate raw material price changes and to buffer unexpected changes in the final good demand. He concluded that the roundwood price adjustment was rapid, justifying the use of an equilibrium model. Kuuluvainen obtained elasticities of short-term demand for sawlogs with respect to own price and sawnwood export price of –0.9 and 1.3, respectively. The estimated elasticity of supply with respect to stumpage price was 3.1. Econometric analyses of the Finnish sawlog market can also be found in Ovas-

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[6] The forest sector is also considered in macro econometric models of Finland, among which the quarterly model of Bank of Finland (BOF4) and Ministry of Finance (KESSU) are the most extensive (see the BOF4 Quarterly Model... 1990, Hetemäki and Kaski 1992).

[7] Later was argued that due to large standing timber inventories, fellings do not measure the traded quantities in the short-run. Also, the use of nominal prices in the Korpinen's study, instead of real prices, clearly improved the estimation results, indicating the possibility of spurious regression between the prices.

kainen (1987) and Tikkanen and Vehkamäki (1987). An aggregate model of wood supply and demand in Finland (including both sawlogs and pulpwood), separating the wood supply from the nonindustrial private forests, public forests, imported wood and the fellings from the forest industry companies' forests was considered in Tervo (1986).

Kuuluvainen et al. (1988) studied demand and supply in both the sawlog and pulpwood markets, as well as pulpwood originating from wood thinnings, using time series data for 1965–1985. The study by Hetemäki and Kuuluvainen (1992) extended Kuuluvainen et al. (1988) by applying modern time series analysis in modelling the Finnish pulpwood market. The new specification was found to be a better statistical representation, suggesting different short-run dynamics, such as the inclusion of significant long-term effects of disposable income and of allowable drain, as also suggested by their theoretical model. Pulpwood demand elasticity with respect to export price could not, however, be estimated. The short-run own-price elasticity in demand was found to be positive and insignificant, while the long-run effect was unitary and negative, as expected. Also, with regard to pulpwood supply, the short-run own-price effect was found to be positive (0.8), but the long-run effect was negative (–0.3).

An error-correction model of the Finnish pulpwood and sawlog markets was estimated in Ripatti (1990). He applied Johansen's (1988) multivariate cointegration analysis to annual data for the period 1960–85. In contrast to other Finnish studies, his results indicated exogenously determined pulpwood stumpage price with a supply elastiticity of 0.4 and a cross-price elasticity of sawlog price of –1.5. The connection between the markets of forest products and roundwood was studied by Forsman and Heinonen (1989), but without explicitly testing for cointegration between time series. The relationship between export prices of forest products and stumpage prices was found to be roughly one to one.

In a game-theoretic bargaining model for the Finnish pulpwood market, Koskela and Ollikainen (1998a) assumed that, in the first stage, the central association of forest owners sets the timber price and the forest industry simultaneously decides on the investments, and that pulpwood demand is determined recursively in the second stage. Using time series data for 1960–1992, they found evidence that pulpwood stumpage price depends positively on the investment plans in the pulp and paper industry. In a further work, Risku (1997) tested the suitability of price-bargaining and efficient bargaining models in the pulpwood market for the period 1961–

94, but only the hypothesis of weak pulp industry in the price bargaining model could be rejected.

To sum up, previous empirical studies on timber markets have been mainly based on an assumption of competitive market structure, often without testing for the competitive conditions (see however, e.g., Bernstein 1992, Bergman and Brännlund 1995 and Murray 1995 for modelling the market as oligopsony, and Koskela and Ollikainen 1998a for using the bargaining approach). From the econometric point of view, the time series properties and possible cointegration between data have only been taken into account in some recent studies of the Finnish roundwood market (e.g. Ripatti 1990 and Hetemäki and Kuuluvainen 1992).

3 MAIN CHARACTERISTICS OF THE FINNISH WOOD MARKET

3.1 Demand for roundwood

Total Finnish use of industrial roundwood (including wood imports) in the pulp and paper industry was 30,7 mill.m^3 (55 % of total market) in 1996, while it was 24,9 mill.m^3 (45 %) in the sawmill and wood based panel industries. In addition, the pulp industry used close to 10 mill.m^3 of wood residues (wood chips and dust) originating from the sawmilling industry. The share of stumpage costs in the total costs of forest industries was 13 %, while labor costs accounted for 17 %, chemicals and supplies 23 % and capital costs for 18 % in 1994 (Seppälä 1995). Nonetheless, in the sawmill industry stumpage costs constitute the main factor share, accounting for over one half of total production costs.

Since 1980 the Finnish paper industry has almost doubled its capacity, most importantly with investments in productive capacity for printing and writing papers. Due to relative price differences between logs and pulpwood, however, 60 % of total stumpage price earnings is paid by the sawmill and plywood industries. In addition, the Finnish forest industry has become increasingly integrated, both horizontally and vertically, during the past decades. Currently there are only three major companies, UPM-Kymmene, Enso and Metsä-Serla, in the Finnish pulp and paper industry. Metsä-Serla is in a special position in the wood market since it acquires wood via the co-operation of the nonindustrial private forest owners (Osuuskunta Metsäliitto). In total, the sawmilling industry consists of 170 large and medium-sized sawmills and over 2000 small sawmills with an average individual annual production of about 300 m^3 (Siekkinen and Pajuoja 1992). The ownership of sawmilling industry is concentrated, since the mills owned by the three biggest forest industry companies comprise about one half of total sawnwood production.

Because intermediary agents purchasing wood and re-selling it to forest industry companies are almost nonexistent in Finland, the big forest industry companies directly purchase the majority of roundwood. The buyer side in the Finnish roundwood market is therefore highly concentrated, and the degree of concentration has increased over time via company mergers and acquisitions. The current market share of the three large forest industry companies in the pulpwood market is approximately between 80–90 % of total harvests. Geographically, buyer concentration differs across the country and by wood assortment. The buyer concentration in central Finland is lower than average, and in northern Finland is higher than average (Västilä and Peltola 1997, see also Naskali 1986). At the regional level, buyer concentration is higher in the pulpwood market than in the sawlog market, as can be implied by the higher average length of wood transportation in the pulpwood market (146 km) as compared to sawlog market (90 km) (Västilä and Peltola 1997).

Wood residues, produced as a by-product in the sawmill industry, accounted for about one quarter of the wood raw materials used in the pulp industry in 1996. Income from wood residue sales account for almost one-fifth of total sales revenue in the sawmilling industry (Nurmi 1985). Wood chip trade is mainly done with internal transfer prices within a company, or with list prices, which the independent sawmilling industry claims are too low compared to the price of pulpwood (e.g. Korkeaniemi 1997). Especially in the mid-1980s the functioning of the wood chip market was questioned both by the government authority for free competition and by the independent sawmills (Nurmi 1985, Sihvonen 1988).

3.2 Supply of roundwood

Private nonindustrial forest owners (NIPFs) accounted for 85 % of roundwood fellings in 1996. The share of private forests in total fellings is significantly higher than the share of privately owned forest area, 62 %. This is due to the fact that private forests are mainly situated in the more fertile areas in the south of Finland. The public forests (forests governed by the Forest and Park Service), situated mainly in the north of Finland, accounted for only 9 % of the fellings but cover 25 % of the forest area. The remaining 6 % of the fellings are derived from forests owned by the forest industry companies.

About one half of NIPF owners belong to local forestry associations, and 25–30 % of the wood from private forests is traded with the help of these associations (Toivonen 1996). Unlike in most European countries, stumpage sales in Finland accounted for 77 % of total harvests from private forests in 1996 (Toivonen 1996, Finnish statistical yearbook of forestry 1997).

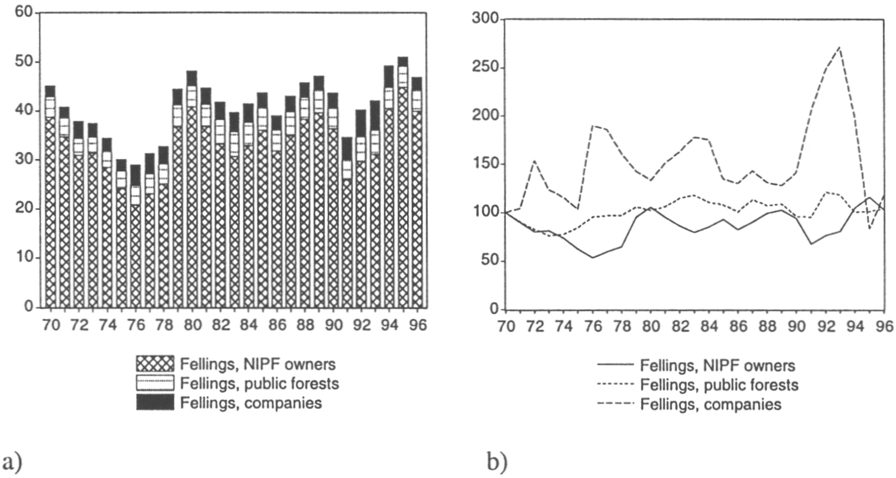

Figure 1. Roundwood fellings from nonindustrial private forests, public forests and forests owned by forest industry by mill.m^3 (a) and by index (b; 1970=100).

In absolute terms, the quantity of roundwood originating from NIPF owned forests fluctuates more strongly than the harvests from public forests, which have been relatively stable aiming for maximum sustainable yield (see Fig. 1–2). Fellings from the forests owned by forest industry companies have also fluctuated strongly, but counter cyclically (see, e.g., Tervo 1986).

The use of domestic pulpwood in 1994–96 accounted for 83 % of the maximum sustainable yield, while the average use of sawlogs was 69 % of maximum sustainable yield (Finnish statistical yearbook of forestry 1997). The utilization rate of forest resources in Finland is higher than the average rate in the European union (Forest Resources of the Temperate Zones... 1990). In international comparisons, wood costs at the mill have been found to be relatively high in Finland (see e.g. Metsä 2000... 1992).

The international trade for roundwood sets limits to price development in domestic timber markets. A significant amount of nonconiferous pulp production in Finland is based on imported wood (Fig. 2). The share of pulpwood imports has increased in recent years, and equaled 16 % of the total wood consumption in 1996. Exports of roundwood remain small, amounting only to about 1 mill.m^3 annually.

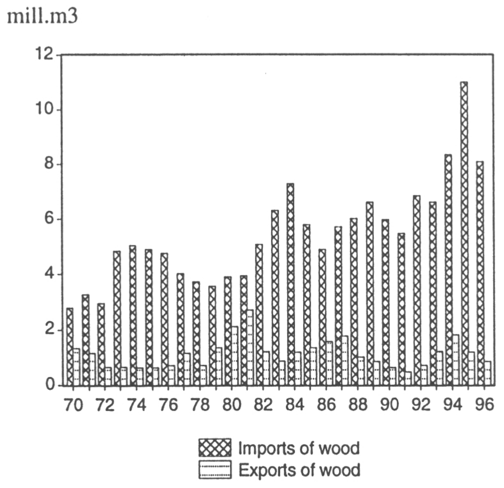

Figure 2. Quantity of Finnish wood imports and exports, including wood chips (mill.m3), 1970–96.

3.3 The stumpage price negotiation system

Fundamental questions concerning the stumpage price agreement system include the following: First, is it economically efficient to try to offset the fluctuations in sawnwood, pulp, and paper markets by institutional arrangements or, instead, should the changes be fully carried through to factor markets? Second, what are the consequences of structural and informational asymmetry between highly concentrated wood industry and a large number of individual NIPF owners? In particular, if the buyer side is in a stronger position in the market, can it force the wood prices to a lower level than would be in a competitive market. Were this the case, it may be justified to allow representatives of wood sellers to collectively negotiate on prices in order to balance the inherent market asymmetry.

During the 1960s, while price recommendations for hardwood logs and pulpwood were made on a national basis, recommendations for sawlogs were negotiated regionally because of the high number of sawmills (Sihvonen 1988). During the 1970s the extent of price recommendations increased. Between the felling seasons 1978/79 and 1990/91, the forestry delegation of the Central Union of Agricultural Producers and Forest Owners, and the Central Association of Forest Industries agreed collectively on recommended stumpage prices on the national level. From the felling season 1984/85 on, negotiations concerned recommendations for traded wood quantities as well. Despite the agreements, actual timber prices were determined in the bargain between an individual forest owner and a wood buyer, transaction by transaction.

The export prices for forest industry products formed a basis for recommended stumpage prices during the period of price negotiations. Stumpage price agreements decreased regional price variation and smoothed out the pulpwood and sawlog price fluctuations during the 1980s by decreasing uncertainty about short-run price development.[8] The real price of sawlogs remained at a constant level during the period of 1960–96, although there were significant variations between years. The real price of pulpwood, however, increased on an average 1 % per annum during the period of 1960–96 (see Fig. 1 in study II). As is usual in factor markets, volatility (based on the standard deviations of time series) in real stumpage prices exceeded the variation in the export prices of pulp, paper or sawnwood. The increased capacity in the pulp and paper industry during the 1980s and 1990s has shifted pulpwood demand upwards, which can explain the increase in the relative price of pulpwood and sawlogs if we assume no relative changes in the supply of different wood assortments.

The nationwide collective price agreement system was broken up in 1991 due to disagreements over stumpage price level between the forest industry and the association of forest owners. During the period from March 1991 to February 1994, there were no price recommendations for the roundwood market. A new agreement was negotiated in the spring 1994, and it was, in many respects, more flexible than previous recommendations. For example, restrictions on wood imports were abolished from the stumpage price agreements.

During the years 1995–96, stumpage price recommendations were negotiated separately in four geographic regions, i.e. southern, eastern, western and northern Finland. From the beginning of 1997, the EU and the Finnish Office of Free Competition gave a temporary permission

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[8] Using non-predictable price variation in regional stumpage prices as an indicator of risk, Tilli (1997) concluded that after the period of collective price agreements the risk connected with forest revenues increased in period 1992–93 in the northern Finland (see also Tilli and Uusivuori 1994).

for a new system with annual discussions regarding stumpage price expectations for the next season between the individual forest industry companies (UPM-Kymmene, Enso) and the representatives of forest owners. The central associations of forest industry or forest owners were no longer allowed to participate in these discussions, but they could provide background market information to these meetings. The functioning and possible continuation of this system will be re-evaluated by the Finnish Office of Free Competition in 1999.

3.4 Regional and assortment specific characteristics of the market

In the previous studies of Finnish roundwood markets, the problem of defining the relevant aggregation level for roundwood markets has largely been neglected. Two dimensions are essential in defining the relevant roundwood market: the proper product dimension of the market and the geographic dimension of the market. Considering the product dimension, the closer substitutes the two products (e.g. spruce and pine sawlogs) are for each other, the more likely it is that they belong to the same market. The geographic dimension of markets is related to the question of whether a price change in one location substantially affects the price in another, in which case both locations effectively belong to the same market.

In Finland, both the forest industry and forest resources (especially in spruce) are unevenly distributed. There are also regional differences in the forest ownership structure (e.g. the dominant role of public forests in the northern Finland). The use of imported roundwood is also varies regionally, being concentrated mainly in eastern Finland. So emerges an important question: are the geographic characteristics of roundwood markets are sufficient to segment the regional markets or are they, despite these characteristics, a bona fide national timber market?

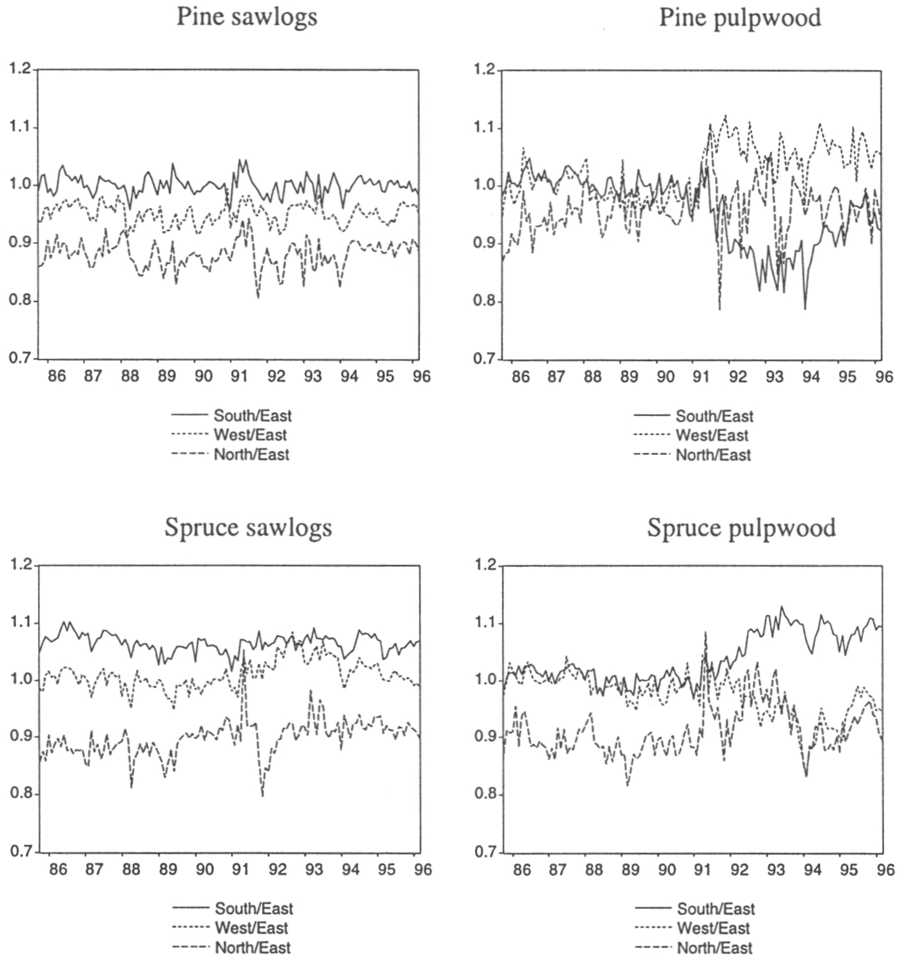

Figure 3. Relative stumpage price development with respect to prices in eastern Finland.

Study of the development of geographic characteristics in the roundwood market is further motivated by the actual stumpage price development between regions (Figure 3). In the pine and spruce sawlog markets, regional price relations have been stable over the period from 1985 to 1996. In contrast, in the pine pulpwood market, the stable price relationship between eastern Finland and the other regions leveled off in 1991 and regional price differences thereafter increased. These changes in relative pulpwood prices coincide with the collapse of the national level stumpage price negotiation system in 1991, which suggests that the system may have especially affected the pulpwood part of the market.

3.5 Market structure in the Finnish wood market

In the following, behavioral characteristics of the Finnish roundwood market are connected with different theoretical assumptions about the market structure, since the econometric roundwood market studies on Finland are inconclusive on the choice of perfect or imperfect competition in the market.

Despite the rather strong assumptions of the competitive market model, it may be a good approximation in a wide variety of circumstances. Even if some of the necessary conditions for perfect competition do not hold, markets can come close to achieving the desired properties of perfect competition (e.g. Carlton and Perloff 1994). In relative terms, the barriers to entry and exit in the sawmilling industry are low, which help competitive conditions to prevail in the sawlog market. In contrast, investments in building a pulp mill take up a considerable amount of capital and last for a substantial time period (one to two years). Therefore structural differences between sawlog and pulpwood markets suggest that there may also be differences in competitive conditions in these markets, and that it is the sawlog market where the competitive market model would be more justified as a starting point. However, the actual price and quantity data (see Fig. 1 in study II) indicate that the development of sawlog and pulpwood prices and quantities follow a reasonably similar pattern in the two markets. Therefore, the assumption of, e.g., a perfectly competitive sawlog market and a monopsony pulpwood market in Finland collapses under scrutiny.[9] A more detailed examination of a data set consisting of average unit wood prices disaggregated by origin, available for the period 1969–86 in Industrial Statistics, indicates that domestic pulpwood prices and the price of imported wood in the pulp industry have been very close to each other. This is in contradiction with the monopsonistic price discrimination hypothesis (e.g. Johansson and Löfgren 1985), and suggests that the international trade in roundwood has indeed set the limits for domestic roundwood price development.[10]

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9 Several studies for Sweden have assumed a competitive sawlog market and a monopsonistic pulpwood market (e.g. Brännlund 1988, 1989).

10 Further, casual evidence of difficulties in negotiating stumpage price agreements suggest that pulpwood buyers could not have behaved as a perfect cartel (e.g. Karp and Perloff 1993). On the other hand, coordination between wood buyers during the 1980s in the form of Teollisuuden puuyhdistys, a joint cooperation of wood buyers to divide the market, has been also well documented (see e.g. Sihvonen 1988).

On the other hand, justification for the alternative hypothesis of a monopsony roundwood market can be found in the spatial aspects of wood markets and in the non-negligible transportation costs of wood. At regional level or during certain years, it is possible that the Finnish sawlog and pulpwood markets have been imperfectly competitive, or that the market has been in disequilibrium (see Brännlund 1991). However, as the focus of this study is mainly on the aggregate roundwood market (except in IV), the possibility of disequilibrium or imperfect competition at the regional level was set aside. The tradition of a stumpage price recommendation system in Finland indicates that there may be characteristics of the market that the competitive market model is not able to capture. However, deviations of actual stumpage prices from the prices agreed upon in the central negotiations (e.g. Tervo 1986) also indicate that actual prices have not been solely determined by the collective recommendations. [11]

Ultimately, it is the empirical performance of the different market models that will give further information on the relevant market structure. In this study of the Finnish sawlog and pulpwood markets we mainly use the competitive market model as a starting point (I, II, IV and V). In order to gain a better understanding of price determination in the pulpwood market, we also explicitly test for potential deviation from competitive pricing in the wood input markets of the pulp industry (III). Throughout the study, roundwood produced outside the private forests is assumed to be exogenous, and it is assumed not to significantly affect the roundwood purchased from the private nonindustrial forest owners.

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[11] Unfortunately no comparable time series exist on agreement prices and actual prices to allow the study of the precise interactions between them. Actual stumpage prices during the study period are volume-weighted regional average prices, while recommendations for stumpage prices in 1978–91 concerned prices for an average stand, tree size, haulage distance and density per hectare.

4 EMPIRICAL ANALYSIS AND DATA

4.1 Econometric methodology

Traditionally, specification of econometric models has been based on theoretical considerations, while less attention has been given to the statistical properties of the data. Indeed, economic theory is about long-run effects and thereby suggests economically well-founded identifying restrictions on the long-run structure, whereas much less is usually known about the short-run structure or adjustment to equilibrium. With respect to roundwood markets, most earlier studies have been implicitly based on the assumption that the underlying data generation processes are stationary, i.e. that the time series at question do not change in mean or variance over time. This research (I to V) differs from the previous roundwood market studies by employing an estimation procedure which draws upon recent advances in time series econometrics (see however Ripatti 1990, Hetemäki and Kuuluvainen 1992).

Advances in time series econometrics, especially in the field of testing for nonstationarity and cointegration between time series data have provided new insights to empirical economic analyses (e.g. Engle and Granger 1987, Johansen 1988, Banerjee et al. 1993, Hamilton 1994). Importantly, if the time series are nonstationary, statistical inference based on conventional t and F tests is invalid and the results obtained may be subject to the "spurious regression" problem (e.g. Granger and Newbold 1974). During the last decade a more statistically-oriented modelling approach has gained ground in time series econometrics as advocated by e.g. Hendry et al. (1988), Hendry (1995) and Spanos (1986, 1990), and denoted hereafter as the Hendry-Spanos-approach (for critical discussion of the methodology, see e.g. Faust and Whiteman 1997). Dynamic error-correction models and the "general to specific" modelling approach are central issues in this methodology (e.g. Davidson et al. 1978, Engle and Granger 1987 and Banerjee et al. 1993). In particular, testing for the existence of unit roots in the data (e.g. Dickey and Fuller 1979, Bhargava 1986) and cointegration between variables have become standard procedures during the 1990s.

A time series is denoted I(0) when it is stationary already in levels and nonstationary and integrated of order d (I(d)) when it must be differenced d times in order to achieve (weak covariance) stationarity (see e.g. Banerjee et al. 1993). Cointegration is essentially based on the idea that there may be a long-run co-movement between trended economic time series so that there is a common equilibrium relation which the time series have a tendency to revert to. Thus, even if certain time series themselves are nonstationary, a linear combination of them may exist that is stationary. Error-correction modelling (e.g. Davidson et al. 1978, Engle and Granger 1987) is inherently based on the idea of incorporating both the long- and short-run effects in the empirical model structure.

The most commonly applied method in testing for cointegration was, up to the early 1990s, the two-step estimation procedure of Engle and Granger (1987). This single-equation method for estimation cointegration relations is, however, based upon a restrictive assumption of a single cointegration relationship, which can be estimated with the ordinary least squares procedure. However, with the case of more than two variables, there may be also more than one equilibrium relation in the model. This leads to the problem of determining the number of cointegration relationships between variables and the identification of these relationships within theoretical model structure.

During the 1990s, a maximum likelihood estimation procedure proposed by Johansen (1988, 1995) has been frequently used in estimating long-run equilibrium relationships. In contrast to single-equation methods, the procedure efficiently includes the short-run dynamics in the estimation of the long-run model structure. The main advantage of the Johansen's vector autoregressive estimation procedure is, however, in the testing and estimation of the multiple long-run equilibrium relationships. Also, the testing of various economic hypotheses via linear restrictions in cointegration space is possible when using Johansen's estimation method (e.g. Johansen and Juselius 1990, 1994). The main weakness in Johansen's modelling approach are its largely unknown small sample properties (e.g. Toda 1995). Higher requirements in Johansen's estimation method for the number of observations than in the Engle-Granger procedure usually necessitates the use of quarterly or monthly time series data, which are not always readily available. Problems in identifying (multiple) cointegration vectors with theoretical economic relationships are also possible when using the Johansen method (see e.g. discussion in Johansen and Juselius 1994).

Prior to modelling, nonstationarity of wood prices and quantities traded for the period 1960–92 was tested using the Augmented Dickey Fuller (Dickey and Fuller 1979) and Perron (1989) tests (II, IV and V). Following the Hendry-Spanos econometric approach we, first, estimate the statistical system for both sawlog and pulpwood prices and quantities to be a congruent representation of a data generating process (I, IV and V). The statistical models summarize the sample information and ensure that the statistical assumptions underlying the model are valid for the data used. Theoretical models of supply and demand determine the variables to be included in the statistical model, but the dynamic specification is dictated by the data. After this, a more parsimonious structural interpretation for the model is sought by introducing zero restrictions from theoretical models. The validity of the structural econometric model is then evaluated by applying various diagnostic tests and testing the forecasting performance of models out of sample (see e.g. Doornik and Hendry 1994).

4.2 Time series data

In analyzing the cyclical behaviour of wood markets, the use of aggregate level time series data is justified, as well as being necessary without access to firm-level or industry-level panel data. When the level of aggregation is high, possible variation between individual agents in the market has to be ignored. Consequently, the models become simple abstractions and many important aspects of the real world have to be disregarded.

In an empirical study, the data constitute an essential component for all following work. The highly disaggregated, assortment-specific monthly time series data used in this study constitute a substantial advantage over previous studies. Both the annual time series for the period 1960–94 (or a sub-sample of it), and the monthly time series for the Finnish roundwood market during the period 1985–97 were used in this study. Time series data in this study cover the aggregate markets for pulpwood and sawlogs (in I–III and V). Because the results of this study (in I, II) indicated structural changes in the roundwood market, monthly time series were used in the empirical analysis (IV, V) to allow use of a shorter study period. The annual data had also too few observations for studying possible cointegration between multiple time series. Instead, by using monthly data, Johansen's multivariate cointegration analysis could be applied (Johansen 1988, 1995, see also applications in Johansen and Juselius 1990, 1994). A drawback, when using monthly or quarterly time series data, however, is seasonal variation in the data, which must be taken into account. In this study, we used seasonal dummy variables to capture the effects of seasonality in data. Alternatively, it would be possible to consider the issue of seasonality in terms of seasonal cointegration as in Hylleberg et al. (1990).

The geographic extent of regional stumpage markets was analysed between four geographic regions in Finland (IV). These regions were specified following the areas used in the regional stumpage price negotiations in 1995–96. The use of regional data facilitated the modelling of different regions and stumpage assortments in more detail than has been done in the previous roundwood market studies for Finland (see however Tilli and Uusivuori 1994, and Tilli 1997).

5 SUMMARY OF THE PAPERS

I Structural changes in sawlog and pulpwood markets in Finland

The aggregate sawlog and pulpwood market models in Kuuluvainen et al. (1988) and Hetemäki and Kuuluvainen (1992) were re-estimated using data for the period 1960–92. The performance of demand and supply models was evaluated with regard to short-term market forecasting. Since annual stumpage prices and quantities turned out to be stationary (see II), valid statistical inference using the levels of these variables was possible.

The main result of the study was that there were signs of structural changes in the market as indicated by diagnostic problems and parameter non-constancy in the models. Therefore, the suitability of these annual models for modelling short-term market behaviour in the institutional environment of the late 1990s was questionable. Also, the elasticities of wood supply were found to increase during the second half of the research period (years 1976–92). One reason for this phenomenon may be that during some years of stumpage price agreements, even a small change in the roundwood unit price increased the amount of wood supplied considerably. Nationwide stumpage price agreements were found to have increased the pulpwood supply and demand, while this effect was absent in the sawlog market. This result suggests that the stumpage price agreement system has had the effect of expanding the pulpwood market.

The behavioural timber-supply model for NIPF owners, allowing for capital market imperfections, was found to be suitable for modelling both the sawlog and pulpwood supply, but was slightly better for the former. This may be related to the higher share of stumpage earnings originating from the sawlog sales (60 %) and to the higher share of wood from the NIPF owners in the sawmilling industry as compared to the pulp and paper industry, which uses large quantities of wood residues and imported roundwood. Thus, the behavioural timber supply model for the NIPF owners can be expected to be better suited for modelling the sawlog market than for modelling the pulpwood market.

II Testing for Granger-causality in the Finnish roundwood market

Interactions between the different Finnish sub-markets, i.e. markets for sawlogs and pulpwood, have not been commonly considered in previous empirical studies. In Kuuluvainen et al. (1988), the effects of changes in sawlog (pulpwood) prices on pulpwood (sawlog) supply were studied by estimating cross-price effects between the two assortments. It can be assumed that if sawlogs and pulpwood are substitutes (complements) in supply, the increase in pulpwood prices increases (decreases) sawlog quantities, and vice versa. Furthermore, if the business cycles in the two industries go in different phases, e.g. if fluctuations in the sawmilling industry lead fluctuations in the pulp industry, it might be possible to use this information in short-term market forecasting.

Bearing this in mind, the causal interrelationships between forest product prices, stumpage prices and traded volumes were studied using Granger's (1969) causality tests. Indeed, sawlog stumpage prices were found to significantly help in forecasting pulpwood prices, but unfortunately for forecasting purposes, the effect has diminished towards the present time. For both wood assortments, lagged stumpage prices helped in forecasting wood quantities for the next felling year, but not vice versa.

Unexpectedly, the results also indicated that price fluctuations in the international markets for forest products have been carried through to domestic wood markets more clearly through the pulpwood part of the market. One explanation for this is that the structural difference between the sawlog and pulpwood markets is related to the differences in the competitive conditions in the forest products markets or in the transmission of the exchange rate effects on the sawnwood and pulp prices. This may represent an interesting area for further research (see however Hänninen 1998, and Hänninen and Toppinen 1998).

III Testing for oligopsony power in the Finnish wood market

There is a strong structural asymmetry between buyers and sellers in the Finnish pulpwood market, i.e. there are few buyers and a large number of small sellers. In the sawlog market the competitive market assumption seems more realistic as compared to pulpwood market because the barriers to entry and exit in the sawmilling industry are low, i.e., the market is contestable, and there are numerous sellers and buyers. Due to this, empirical tests of the competitive market structure hypothesis in the input markets of the pulp industry is of primary interest.

Following Appelbaum (1982), as well as the previous applications on the roundwood markets by Bergman and Brännlund (1995) and Murray (1995), a flexible-form factor demand system was estimated for the Finnish pulp industry. The existence of oligopsony power was tested by estimating a markup of the value of the marginal product of pulpwood over the actual pulpwood price. This procedure was also applied to analysing the demand for wood chips used in the pulp industry.

Using time series data from 1965 to 1994, the results from a model with a constant markup term suggested that pulpwood price did not deviate significantly from the competitive market price. With regard to market for wood chips, though, some indication was found of wood chip pricing below the value of marginal product. However, the results for the pulpwood market were sensitive to having the whole period included in the estimation; if dummy variables were included in the estimation to account for unexplained variation in the mid 1970s, the competitive market hypothesis was rejected. Therefore, due to this and to the use of aggregate market level data in the estimation, the obtained results should be considered with caution. Further empirical work on pricing in the pulpwood market, preferably using firm-level data, would provide more confidence as to the robustness of our test results.

IV Roundwood market integration in Finland: a multivariate cointegration analysis

In this study geographical characteristics of the Finnish roundwood market were examined by testing the long-run law of one price (LOP) between stumpage prices for four geographic regions, i.e. southern, eastern, western and northern Finland. The sawlog and pulpwood markets were disaggregated into spruce and pine sawlogs and pulpwood, respectively. Testing the hypothesis of full market integration between the four regions was consistent with testing that the cointegration rank in Johansen's cointegration analysis equals three for each stumpage assortment (for previous empirical applications of the Johansen procedure in testing market integration, see e.g. Goodwin and Grennes 1994). The acceptance of market integration itself does, however, not necessarily imply that the market is perfectly competitive, because our null hypothesis incorporated the competitive market assumption rather than being a direct test for it.

According to the test results, pine sawlogs were the only wood assortment where the test for full market integration (LOP) could not be rejected. However, the differences between wood assortments in statistical tests were not very great and any conclusions on behavioral differences across different wood assortments are difficult to make. To check the robustness of the market integration test, we re-estimated cointegration vectors using two sub-samples of data, 1985:10–1991:02 and 1991:03–1996:03, breaking the sub-samples at the end of central price recommendations. Bearing in mind the possible loss in the reliability of cointegration tests, as they were weakened by the shortness of the data series, our results indicated that, for pine and spruce pulpwood, the hypothesis of full market integration was not rejected using the data for 1985–91 but it was rejected for the period 1991–96. Accordingly, market integration for both pulpwood assortments in Finland appears to have diminished during the 1990s as compared to the period of comprehensive price recommendations. Using dynamic error-correction models, the effect caused by this structural break was, however, not found to be statistically significant in any of the markets. Furthermore, pine sawlog and spruce pulpwood stumpage prices in eastern Finland were found to be weakly exogenous to the prices in other regions. In both pulpwood assortments, the source of price fluctuation was found to be southern Finland. Thus, causation between regional prices originated mainly from the largest wood-using regions, possibly reflecting the fact that demand forces are driving the market more strongly than factors related to timber supply.

V Incorporating cointegration relations in a short-run model of the Finnish sawlog market

A priori, it appears likely that some of the time series in the roundwood market may be integrated and that cointegration relations may exist between the individual time series. Thus, there may be a number of equilibrium relations in the market. Hetemäki and Kuuluvainen (1992) studied time series properties in pulpwood market and Ripatti (1990) in both the sawlog and pulpwood markets in Finland. However, they used annual data, which gives only a few observations in any given period of similar institutional environment. By contrast, in this study it was possible to use monthly data and Johansen's cointegration analysis for modelling short- and long-run relations in the market.

The equilibrium assumption was found to be suitable for explaining the price and quantity determination in the Finnish sawlog market. More precisely, there was evidence of two equilibrium relationships, which could be identified as the supply of, and demand for, sawlogs. The sawlog demand relationship was established between sawlog stumpage price, sawlog quantity, sawnwood price and capital stock, while the supply relation in the perfect capital markets consisted of sawlog price, sawlog quantity, real interest rate, and the effect of increasing forest inventory as captured by the linear trend.

In general, the results coincided with the theoretical hypotheses, since all the coefficients had correct signs and significant t-values. For example, with respect to sawlog demand the estimated own-price elasticity, –1.5, was comparable with results from previous models of Finnish markets, i.e. –0.9 in Kuuluvainen (1986) and –1.3 in Kuuluvainen et al. (1988). The elasticity of interest rate was positive in the supply model, which is consistent with the perfect capital market assumption during the research period. The estimated supply elasticity of sawlogs was 1.6, i.e., higher than the estimates in some previous studies based on the imperfect capital market hypothesis (e.g. Hetemäki and Kuuluvainen 1992 and study I). Contrary to earlier findings, in the supply model stumpage price had a positive effect both in the short- and long-run, while only the long-run own-price effect was significantly present in the sawlog demand relationship.

6 CONCLUSIONS

The main contribution of this research has been new information as to the structure and functioning of the Finnish roundwood market. Specifically, this research breaks new ground in three main areas. First, the results of this study provide new information on the specific aspects of the market that can be used in developing short-term forecasting models for roundwood price and quantity determination (I–V). Second, methodological improvements in time series econometrics and an improved statistical basis (i.e. monthly market data in IV and V) facilitate the use of more sophisticated modelling techniques, compared to previous roundwood market studies. Third, in addition to the competitive market model which was used as a starting point in the empirical analysis of studies I, II, IV and V, competitive conditions in the pulpwood market are evaluated with regard to the effects of the stumpage price recommendation system (I and IV) and to the existence of oligopsony power in the wood input markets of the pulp industry (III).

Although the Finnish roundwood market is asymmetric in its structure, i.e. there are many sellers and few buyers, and both parties have been involved in a tradition of central negotiations, there is still no clear-cut evidence against the competitive market model. In fact, the competitive market model was found to be a reasonably good approximation for modelling price and quantity determination in many cases, especially for sawlogs. The obtained elasticities in models were broadly consistent with the theoretical hypotheses about demand and supply relationships in the market. As expected from the developments in the institutional background, i.e. the effects of imperfect capital markets were less distinquishable in the models using data from the late 1980s and 1990s than in models with data starting from the early 1960s.

Regarding the regional characteristics of the market, the hypothesis of the law of one price (LOP) between four main regions in Finland, was found to be valid in the case of pine sawlogs during the period 1985–96. In the markets for spruce sawlogs and pine and spruce pulpwood the hypothesis of the LOP did not hold, although it did hold for the pulpwood market using only data for the period of 1985–91.

In testing for the oligopsony power in the pulpwood market the competitive market hypothesis could not be rejected, while there were more clearly signs of imperfect competition in the pricing of wood chips (III). In the highly capital-intensive pulp industry, a decision to close down a pulp mill due to lack of its primary input would cause a major loss in profitability for a firm, which may counteract the differences in market asymmetry between sawlog and pulpwood markets. The relevant market structure in the Finnish pulpwood market is, most likely, somewhere between a monopsony and a competitive market rather than at either extreme, and according to the results of this study we argue that it is closer to perfect competition than to monopsony.

The significant effect of stumpage price agreement system on the pulpwood market, however, suggests that there are some features of the pulpwood market that the competitive or monopsonistic market models are not able to capture (I, IV). Remembering that a competitive market is one that requires no intervention to improve its performance, the significant effect of stumpage price negotiations on the pulpwood market suggests that the competition in the market is not perfect. Further work, both theoretical and empirical, on modelling competition in the Finnish forest sector is therefore necessary.

Nevertheless, most importantly, it is the international market for roundwood that sets the limits for the domestic roundwood market. In the future progress of economic and monetary integration (EMU) within the European union, the fluctuations in the export markets of forest industry products are likely to be carried through more directly to the Finnish roundwood market. Higher transparency of wood prices between different countries in the EMU environment may enhance competition by increasing the degree of roundwood market integration between countries. Anticipating further economic integration in Europe, the study of the price interrelationships between timber markets in Finland and major competitor countries (e.g. Sweden, Austria) would be of interest and may reveal useful information on the functioning of roundwood markets in general.

This research focused almost exclusively on modelling the interrelationships between private nonindustrial forest owners and forest industry (I, II, IV and V) in Finland. Therefore it could be of further interest to consider timber supply from other forest ownership groups (e.g. Tervo 1986). For example, the effects of increased wood imports on the equilibrium in the domestic roundwood markets should be analyzed with recent data for the 1990s. Further work is also needed in the simultaneous modelling of the Finnish sawlog and pulpwood markets.

It may be noted that the results of this study regarding the nonstationarity of monthly stumpage prices (IV, V) differ from studies using annual stumpage prices in Finland (I, II). The test results on time series properties of stumpage prices also differ from some studies in North America, which have tested stationarity of wood prices, a necessary condition for informational inefficiency of stumpage markets. The results of Washburn and Binkley (1990), Haight and Holmes (1991), Zhang and Binkley (1994) and Newman and Yin (1996) have indicated that monthly time series follow autoregressive processes, while quarterly average series or annual series have often been found to be nonstationary. The issue is interesting since time series properties of stumpage prices have implications for the optimal timing of timber harvests; the optimal policies for autoregressive prices involve harvesting when stumpage price is above the historical average (i.e. a reservation price policy), while the optimal policy for nonstationary prices is to cut when the price is low relative to the historical average.

Overall, the results of this study have implications for practical decision-making in the forest sector. For example, the importance of institutional arrangements and the signs of imperfect competition in the market, together with regional characteristics in the markets for different wood assortments, all stress the importance of maintaining and developing publicly available market information services for the Finnish roundwood market (see e.g. Boyd and Hyde 1989).

REFERENCES

Adams, D. & Blackwell, J. 1973. An econometric model of the United States forest products industry. Forest Science. Vol 19, 82–96.

Adams, D. & Haynes, R. 1980. The softwood timber assessment market model: structure, projections and policy simulations. Society of American Foresters. Forest Science Monograph 22. 64 p.

Appelbaum, E. 1982. The estimation of the degree of oligopoly power. Journal of Econometrics. Vol 12, 287–299.

Banerjee, A., Dolado, J., Galbraith, J. & Hendry, D. 1993. Co-integration, error-correction, and the economic analysis of non-stationary data. Oxford University Press, Oxford. 329 p. ISBN 0–19–828700–3.

Bergman, M. 1992. Differences in final felling and thinning behaviour between owner categories in Sweden. Scandinavian Journal of Forest Research. Vol 7, 269–283.

Bergman, M. & Brännlund, R. 1995. Measuring oligopsony power. An application to the Swedish pulp and paper industry. Review of Industrial Organization. Vol 10, 307–321.

Bernstein, J.J. 1992. Price margins and capital adjustment. Canadian mill products and pulp and paper industries. International Journal of Industrial Organization. Vol 10, 491–510.

Bhargava, A. 1986. On the theory of testing unit roots in observed time series. Review of Economic Studies. Vol 53, 369–384.

Binkley, C. 1987. Economic models of timber supply. In Kallio, M., Dykstra, D.P. & Binkley, C.S. (eds.): Global Forest Sector. John Wiley, Chichester. pp. 109–133.

BOF4 Quarterly model of the Finnish economy. 1990. Bank of Finland. D:73. ISBN 951–686–248–9.

Boyd, R. & Hyde, W. 1989. Forestry sector intervention. Chapter 4: The impacts of public regulation on social welfare. Iowa State University Press, Ames. pp. 90–118.

Brännlund, R. 1988. The Swedish roundwood market. An econometric analysis. Dissertation. Umeå Universitet, institution för skogsekonomi. Rapport 82. Umeå. 187 p. ISBN 91–576–3436–X.

Brännlund, R. 1989. The social loss of imperfect competition: the case of the Swedish pulpwood market. Scandinavian Journal of Economics. Vol 91, 689–704.

Brännlund, R. 1991. Disequilibrium and asymmetric price adjustment. The case of the Swedish timber market. Empirical Economics. Vol 16, 417–431.

Brännlund, R., Johansson, P-O. & Löfgren, K-G. 1985. An econometric analysis of aggregate sawtimber and pulpwood supply in Sweden. Forest Science. Vol 31, 595-606.

Carlton, W. & Perloff, J. 1994. Modern industrial organization. Second edition. Harper Collins, New York. 973 p. ISBN 0–673–46902–6.

Carter, D. 1992. Effects of supply and demand determinants on pulpwood stumpage quantity and price in Texas. Forest Science. Vol 38, 652–660.

Davidson, J.E.H., Hendry, D.F., Srba, F. & Yeo, S. 1978. Econometric modelling of the aggregate time-series relationship between consumers' expenditure and income in the United Kingdom. Economic Journal. Vol 88, 661–692.

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. Co-integration and error correction: Representation, estimation and testing. Econometrica. Vol 55, 251–276.

Faust, J. & Whiteman, C. 1997. General-to-specific procedures for fitting a data-admissible, theory-inspired, congruent, parsimonious, encompassing, weakly-exogenous, identified, structural model to the DGP: A translation and critique. Carnegie-Rochester Conference Series on Public Policy. Vol 47, 121–161.

Forsman, P. & Heinonen, T. 1989. Dynamic models of the roundwood market in Finland. Finnish Economic Papers. Vol 2, 48–54.

Finnish statistical yearbook of forestry. 1997. Finnish Forest Research Institute. Gummerus, Jyväskylä. ISBN 951–40–1585–1. 348 p.

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.

Granger, C.W.J. 1969. Investigating causal relations by econometric models and cross-spectral methods. Econometrica. Vol 37, 424–438.

Granger, C.W.J. & Newbold, P. 1974. Spurious regressions in econometrics. Journal of Econometrics. Vol 2, 111–120.

Haight, R. & Holmes, T. 1991. Stochastic price models and optimal tree cutting: results for loblolly pine. Natural Resource Modelling. Vol 5, 423–443.

Hamilton, J.D. 1994. Time series analysis. Princeton University Press, Princeton. 816 p. ISBN 0–691–04289–6.

Haynes, R. 1977. A derived demand approach to estimate the linkage between stumpage and lumber markets. Forest Science. Vol 23, 281–288.

Hendry, D. 1995. Dynamic econometrics. Oxford University Press. 869 p. ISBN 0–19–828–317–2.

Hendry, D., Neale, A., & Srba, F. 1988. Econometric analysis of small linear systems using PC-FIML. Journal of Econometrics. Vol 38, 203–226.

Hetemäki, L. 1990. Factor substitution in the Finnish pulp and paper industry. Acta Forestalia Fennica 211. 87 p. ISBN 951–40–1093–0.

Hetemäki, M. & Kaski, E-L. 1992. KESSU IV An Econometric model of the Finnish economy. Ministry of Finance. ISBN 951–47–5859–5.

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

Hultkrantz, L. & Aronsson, T. 1989. Factors affecting the supply and demand of timber from private nonindustrial lands in Sweden: An econometric study. Forest Science. Vol 35, 946–961.

Hylleberg, S., Engle, R.., Granger, C.. and Yoo, S. 1990. Seasonal integration and cointegration. Journal of Econometrics. Vol 44, 215–238.

Hänninen, R. 1986. Demand for Finnish sawnwood exports in Western Europe, 1962–83. Folia Forestalia 657. 25 p. ISBN 951–40–0738–7.

Hänninen, R. 1998. Exchange rate changes and the Finnish sawnwood demand and price in the UK market. Silva Fennica. Vol 32, 61–73.

Hänninen, R. & Toppinen, A. 1998. Price effects of exchange rate changes in the Finnish pulp and paper exports. 27 p. (forthcoming in Applied Economics)

Johansen, S. 1988. Statistical analysis of cointegrating vectors. Journal of Economic Dynamics and Control. Vol 12, 231–254.

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

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. 1994. Identification of the long-run and short-run structure: An application to the ISLM model. Journal of Econometrics. Vol 63, 7–36.

Johansson, P.O. & Löfgren, K.G. 1985. The economics of forestry & natural resources. Basil Blackwell Ltd, Oxford. 292 p.

Karp, L. & Perloff, J. 1993. A dynamic model of oligopoly in the coffee export market. American Journal of Agricultural Economics. Vol 75, 448–457.

Korkeaniemi, A. 1997. Sahahakkeen käyttöarvo massan valmistuksessa. Puumies 6. 1 p.

Korpinen, P. 1980. Tukkipuun kysyntä ja tarjonta 1950–78. Työväen taloudellinen tutkimuslaitos. Tutkimusselosteita 11. 10 p. (in Finnish)

Koskela, E. 1989a. Forest taxation and timber supply under price uncertainty: perfect capital markets. Forest Science. Vol 35, 137–159.

Koskela, E. 1989b. Forest taxation and timber supply under price uncertainty: credit rationing in the capital markets. Forest Science. Vol 35, 160–172.

Koskela, E. & Ollikainen, M. 1998a. A game-theoretic model of timber prices with capital stock: an emprical application to the Finnish pulp and paper industry. Forthcoming in the Canadian Journal of Forest Research.

Koskela, E. & Ollikainen, M. 1998b. Mandatory biodiversity conservation: competitiveness versus green image effects. University of Helsinki, Department of Economics. Discussion Papers (forthcoming).

Kuuluvainen, J. 1986. An econometric analysis of the sawlog market in Finland. Journal of World Forest Resource Management. Vol 2, 1–19.

Kuuluvainen, J. 1989. Nonindustrial private timber supply and credit rationing. Microeconomic foundations with empirical evidence from Finnish case. Sveriges lantbruksuniversitet, instutionen för skogekonomi. Rapport 85. 244 p.

Kuuluvainen, J. 1990. Virtual price approach to short-term timber supply under credit rationing. Journal of Environmental Economics and Management. Vol 19, 109–126.

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. & Karppinen, H. 1996. Landowner objectives and non-industrial private timber supply. Forest Science. Vol 42, 300–309.

Kuuluvainen, J. & Tahvonen, O. 1997.Testing the forest rotation model: evidence from panel data. Metsäntutkimuslaitoksen tiedonantoja 644. 36 p. ISBN 951–40–1570–3.

Laaksonen, S., Toppinen, A., Hänninen, R. & Kuuluvainen, J. 1997. Cointegration in Finnish paper exports to the United Kingdom. Journal of Forest Economics. Vol 3, 171–185.

Leuschner, W.A. 1973. An econometric analysis of the Wisconsin aspen pulpwood market. Forest Science. Vol 19, 41–46.

Merrifield, R. & Haynes, R. 1983. Production function analysis and market adjustments: An application to the Pacific Northwest forest products industry. Forest Science. Vol 29, 813–822.

Metsä 2000-ohjelman tarkistustoimikunnan mietintö. 1992. Maa- ja metsätalousministeriö. Komiteanmietintö 1992:5. Valtion painatuskeskus, Helsinki. ISBN 951–47–3837–3. 116 p. (in Finnish)

Murray, B.C. 1995. Measuring the oligopsony power with shadow prices: U.S. Markets for pulpwood and sawlogs. The Review of Economics and Statistics. Vol LXXVII, 486–498.

Naskali, A. 1986. Keskittymisindeksit ja osatajien keskittyminen Pohjois-Suomen raakapuu-markkinoilla. (Summary: Concentration indices and buyer concentration in the round-wood markets in Northern Finland). Folia Forestalia 680. 44 p.

Newman, D. 1987. An econometric analysis of the southern softwood stumpage market: 1950–80. Forest Science. Vol 33, 932–945.

Nurmi, M. 1985. Sahatavaran hinta- ja kilpailutilanteesta. Elinkeinohallitus. Tutkimusosasto. Selvityksiä 1/85. 86 p. (in Finnish)

Ollikainen, M. 1996. Essays on timber supply and forest taxation. Government Institute for Economic Research. VATT Research reports 33. Helsinki. ISBN 951–561–169–5.

Ovaskainen, V. 1987. On timber supply decisions under liquidity constraints and project indivisibility. Licentiate thesis. University of Helsinki, Faculty of Agriculture and Forestry. 106 p.

Ovaskainen, V. 1992. Forest taxation; timber supply, and economic efficiency. Acta Forestalia Fennica 233. ISBN 951–40–1266–6. 88 p.

Ovaskainen, V. & Kuuluvainen, J. (eds.) 1994. Yksityismetsien rakennemuutos ja metsien käyttö. Metsäntutkimuslatioksen tiedonantoja 484. 122 p. ISBN 951–40–1345–X. (in Finnish)

Pajuoja, H. 1995. Kulutus ja hakkuukäyttäytyminen kirjanpitotiloilla. (Summary: Consumption and harvesting decisions on book-keeping farms in Finland). Doctoral thesis. Publications of the Department of Forest Economics 3, University of Helsinki. 81 p. (in Finnish)

Perron, P. 1989. The Great Crash, the oil price shock, and the unit root hypothesis. Econometrica, Vol 57, 1361–1401.

Ripatti A. 1990. Raakapuun kysyntä ja tarjonta Suomessa. Empiirinen tutkimus pitkän aikavälin riippuvuuksista. M.Sc. thesis in Economics, University of Helsinki. 93 p. (in Finnish)

Ripatti, P.1996. Factors affecting partitioning of private forest holdings in Finland. A logit analysis. Acta Forestalia Fennica 252. 84 p. ISBN 951–40–1534–7.

Risku, I. 1997. A bargaining approach to the Finnish pulpwood market. Licentiate thesis. Department of Economics, University of Helsinki. 77 p.

Robinson, V.L. 1974. An econometric model of softwood lumber and stumpage markets, 1947–1967. Forest Science. Vol 20, 171–179.

Seppälä, H. 1995. Metsäteollisuuden kustannukset ja kannattavuus. (ed. Hetemäki, L.) Metsäsektorin ajankohtaiskatsaus 572, p. 33–36. (in Finnish)

Sherif, F. 1983. Derived demand of factors of production in the pulp and paper industry. Forest Products Journal. Vol 33, 45–49.

Siekkinen, V. & Pajuoja, H. 1992. Small sawmills in Finland, 1990. Folia forestalia 784. 19 p. (in Finnish)

Sihvonen, A. 1988. Raakapuumarkkinat Suomessa: markkinoiden rakenne ja kilpailuolosuhteet. Elinkeinohallitus, tutkimusosasto. Selvityksiä 1988(1). 96 p. (in Finnish)

Spanos, A. 1986. Statistical Foundations of Econometric Modelling. Cambridge University Press. ISBN 0–521–26912–1. 695 p.

Spanos, A. 1990. The simultaneous equations model revisited. Journal of Econometrics. Vol 44, 87–105.

Tahvonen, O. 1997. Forest age classes and rotation periods in a continuous time life cycle model for nonindustrial private forest owners. Metsäntutkimuslaitoksen tiedonantoja 629. 35 p. ISBN 951–40–1552–5.

Tervo, M. 1986. Suomen raakapuumarkkinoiden rakenne ja vaihtelut. Summary: The structure and fluctuations of Finnish roundwood market. Communicationes Instituti Forestalis Fenniae 137. ISBN 951–40–0756–5. 66 p. (in Finnish)

The forest resources of the temperate zones. The UN-ECE/FAO 1990 Forest resource assessment. 1990. Volume I. ECE/TIM/62. United Nations, Geneva. ISBN 92–1–116552–0. 348 p.

Tikkanen, I. & Vehkamäki, S. 1987. Yksityismetsien havutukkien kysyntä ja tarjonta: Havutukkimarkkinoita koskeva ekonometrisen analyysin ennakkoraportti. University of Helsinki. Department of Social Economics of Forestry, research reports 14. 51 p. (in Finnish)

Tilli, T. 1997. Metsäpääoman tuotoksen realisointiin liittyvä riski. Puun ennustamaton hintavaihtelu riskin mittarina Suomessa vuosina 1985–91 ja 1991–93. Pellervon taloudellinen tutkimuslaitos. Raportteja ja artikkeleita 148. 91 p. ISBN 951–8950–64–4. (in Finnish)

Tilli, T. & Uusivuori, J. 1994. Puun hintavaihtelut Suomessa 1985–91 ja 1991–93. Pellervon taloudellinen tutkimuslaitos. Raportteja ja artikkeleita 132. 51 p. ISBN 951–8950–X. (in Finnish)

Tirole, J. 1988. The theory of industrial organization. MIT Press, Cambridge. 479 p. ISBN 0–262–20071–6.

Toda, H. 1995. Finite sample performance of likelihood ratio tests for cointegrating ranks in vector autoregression. Econometric theory. Vol 11, 1015–1032.

Toivonen, R. 1996. Raakapuumarkkinat ja markkinainformaatio eri maissa. Department of Forest Economics, University of Helsinki. Reports 8. ISBN 951–45–7478–8. 62 p. (in Finnish)

Yin, R. & Newman, D. 1996. Are markets for stumpage informationally efficient? Canadian Journal of Forest Research. Vol 26, 1032–1039.

Varian, H. 1993. Microeconomic analysis. 3rd Edition. W.W. Norton & Co, New York.

Washburn, C. & Binkley, C. 1990. Informational efficiency of markets for stumpage. American Journal of Agricultural Economics. Vol 72, 394–405.

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

Zhang, D. & Binkley, C. 1994. The informational efficiency of the Vancouver log market and the financial risk of holding logs in storage. Canadian Journal of Forest Research. Vol 24, 550–557.

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Structural Changes in Sawlog and Pulpwood Markets in Finland

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This paper presents a short-term econometric model for the sawlog and pulpwood markets in Finland. More specifically, the effects of structural changes in the market on the success of short-term market modelling are investigated. Wood prices and quantities traded are stationary. Therefore, valid statistical inference using the levels of these variables is possible. Pulpwood prices were found to be directly proportional to sawlog prices during the study period, and the cross-price effects were not statistically significant. The results indicated that the price sensitivity of wood supply in Finland increased during the 1980s and early 1990s. Nationwide collective price agreements were found to have increased the level of pulpwood supply and demand from private forests, but to have had no effect on either supply of or demand for sawlogs. Due to a structural change in the 1970s, the models estimated for the whole period cannot be used for short-term forecasting in the 1990s. Higher-than-annual frequency data should be used in developing accurate short-term forecasting models. *Key words: roundwood market, structural change, time-series econometrics, Finland.*

INTRODUCTION

The aim of the study was to estimate an econometric model for the Finnish sawlog and pulpwood markets. Timber markets have been the focus of considerable interest in forest economics research in recent decades. Previous studies in the USA (e.g. Adams & Haynes 1980, Newman 1987, Murray 1995) and in Scandinavia (e.g. Brännlund 1988, Kuuluvainen et al. 1988, Hetemäki & Kuuluvainen 1992) have established the basic factors affecting price and quantity determination in timber markets. This study demonstrates that changes in the institutional environment and in the structure of the market may have substantial effects on the parameters of a short-term forecasting model.

Roundwood markets in Scandinavia are characterized by strong cyclical fluctuations in prices and quantities, because the forest industries in these countries depend heavily on volatile export markets. For example, in Finland only 10% of paper and paperboard output and 25% of sawnwood output is used domestically. An arrangement for comprehensive stumpage price recommendations at the national level prevailed in Finland in the felling years 1978/79–1990/91. Since the mid-1980s, company mergers in the Finnish forest industries have increased buyer concentration in the wood market. The most influential change in the economic environment of Finnish non-industrial private forest owners (NIPFs) has been the capital market liberalization, which was completed in Finland by 1986. In the beginning of 1990s, competition legislation governing the timber market was revamped in Finland, as also in Sweden and Norway.

These changes could have had an impact on the market behaviour of non-industrial private forest owners and the forest industry in the roundwood market. The effects of buyer concentration cannot be readily observed using the equilibrium market model developed here. Therefore, our results concern primarily the effects of the nationwide recommended price agreements and possible effects of capital market liberalization on the determinats of the non-industrial private timber supply.

We follow Hetemäki & Kuuluvainen (1992) in utilizing the recent developments in time series econometrics (e.g. Hendry et al. 1988), which allow for more reliable inferences regarding the short-run market behaviour, but we extend their pulpwood supply and demand model to cover the sawlog market. Annual data for the period 1960–1992 are used. The stationarity of the time series data is tested initially for valid statistical inference. Also, the exogeneity of timber prices is tested explicitly. According to our results, the price elasticity of wood supply in Finland increased during the 1980s. Nationwide recommended price negotiations have had an effect on the supply and demand for pulpwood only.

Theoretical framework

Roundwood market studies have generally assumed perfect competition (cf. Brännlund et al. 1985). Currently in Finland there are only three buyers representing the pulp and paper industry and these buyers also represent a significant part of the sawtimber market. In spite of this, empirical studies using the competitive market hypothesis have so far performed well in describing the Finnish timber markets (Kuuluvainen et al. 1988, Hetemäki & Kuuluvainen 1992). The theoretical framework for the present study is also based on a simultaneous equation equilibrium market model with perfect competition. This is justified by the fact that company mergers have had a major impact only since the mid-1980s.

The behavioural timber supply function that we use has been derived from a two-period consumption–savings model of a utility maximizing representative NIPF owner with effective credit rationing in the capital market. Up to the mid-1980s the assumption of effective credit rationing is justified because interest rates were then regulated directly by the Bank of Finland. Binding credit rationing makes the optimal decisions to supply timber and to consume goods and services simultaneous (Koskela 1989, Kuuluvainen et al. 1996). Subsequently, the timber supply depends not only on present and expected (second period) stumpage prices, the expected interest rate and the initial growing stock but also on present and expected non-stumpage income of the forest owner. Thus we assumed that timber supply is a function of prices, non-forestry income, interest rate and current timber stock as follows:

$$Q^s_t = Q(\underset{+/-}{c_t}, \underset{-/+}{c_{t+1}}, \underset{-}{m_t}, \underset{+}{m_{t+1}}, \underset{-}{r_{t+1}}, \underset{+}{v_t}), \quad (1)$$

where Q is quantity of wood supplied, c is stumpage price, m is non-forestry income, r is the market interest rate and v is the timber stock at the beginning of each observation period (year). In the empirical analysis we assumed two separate submarkets, i.e. for pulpwood and sawlogs, and used the same behavioural model to estimate the supply functions separately (cf. Brännlund 1988, Newman 1987). The comparative static effects indicated below the parameters show that the elasticities of supply with respect to present and expected prices can be either positive or negative. Under effective credit rationing, the interest rate only has a negative income effect; the positive substitution effect of a perfect capital market is absent. For formal derivation of this equation and a detailed discussion of the comparative static effects under perfect and imperfect capital markets, the reader is referred to Kuuluvainen (1990) or under capital market imperfections and *in situ* valuation of the timber stock to Kuuluvainen et al. (1996). The current period (period 1 in the two-period model) in Eq. (1) is denoted by the subscript t, and $t+1$ refers to the second-period values of the two-period model. The second-period values, which are known with certainty in the theoretical model, must be replaced by expectations in the empirical specification.

The non-forestry income of the theoretical model was measured by disposable income in the empirical estimations. This can be justified because during the period studied forest income was subject to a lump sum yield tax, which is independent of the amount of timber sold. According to the two-period model, other owner-specific factors, e.g. the subjective rate of discount of the owner, his/her age and the possible credit limit, also affect the supply decisions, but it was not possible to measure these in the empirical estimation using aggregate data. However, these variables can be assumed to be distributed randomly in the data and their effects are captured by the error term. Harvesting costs were not included in the theoretical model because they are a constant fraction of the wood price at the factory over a business cycle and thus do not affect the short-run supply or demand.

The representative forest industry enterprise was assumed to sell its outputs (Y_i) in competitive markets at a given price. The output of the forest industry firm can be described using a continuous, strictly concave and twice differentiable production function, $Y=f(K, L, Q)$, where K is capital input, L is labour input and Q is material (roundwood) input. The other inputs, most importantly other materials and energy, were excluded owing to practical problems related to consistent measurement of their prices (see Hetemäki 1990). Using Hotelling's lemma, partial differentiation of the profit function with respect to roundwood price yielded the roundwood demand functions for sawlogs and pulpwood. The roundwood demand functions were assumed to be homogeneous of degree zero with respect to factor prices, i.e. the demand for inputs was determined by the relative prices of inputs and not by the absolute price levels. Consequently, the demand function for roundwood, i.e. sawlogs or pulpwood, could be expressed as:

$$Q_t^d = Q(\underset{+}{p_t}, \underset{-}{c_t}, \underset{+/-}{w_t}, \underset{+/-}{u_t})$$

where p is the export price of final products, c is stumpage price, w is wage cost and u is the price of capital. The expected signs below the explanatory variables indicate that a priori labour and capital can be either substitutes or complements for wood in sawnwood or pulp production.

The dynamic specifications of the demand and supply equations are based on the data, because the theoretical behavioural equations do not indicate the form of expectation mechanism and the economic theory actually describes a long-run (equilibrium) relationship.

MATERIAL AND METHODS

Because NIPFs are the main forest ownership category, accounting for about 62% of total forest area in Finland and over 70% of the total commercial harvest, the quantity and price data of the present study cover only the purchases of timber from private non-industrial lands. The dependent variables in the structural demand and supply equations are coniferous sawlogs and total pulpwood purchased from private forests. These and the respective stumpage prices, net harvesting and transportation costs, have been reported by felling season. Wood traded in a felling season is used mainly in the following calendar year. Therefore, we used wood prices and quantities for, e.g. a felling year 1990/91, to represent a calendar year, 1991. A wood chip negotiation price variable and representative firm's average price after the negotiation period was used to measure the average price of wood chips sold by the sawmill industry to the pulp industry.

Unit export values of coniferous lumber for the sawlog market and pulp for the pulpwood market were used to describe the export prices of forest products. Labour costs in sawmills and pulp and paper industries were measured by the sum of wages and social security costs divided by total working hours. For the years 1960–1973 social security costs were not available, and thus we used an approximation of the social security cost percentage for the paper industry from Hetemäki (1990). Developments in the sawmill industry were assumed to be similar to those in the pulp and paper industry. The basic formula for user cost, $U = q(nr + d)$, where q is the implicit price index of investment, nr is the nominal interest rate and d is the constant rate of capital depreciation, was used for the sawmill and pulp and paper industries.

The average commercial bank lending rate was used as the interest rate variable. The real rate of interest was obtained by subtracting the annual inflation rate (measured here by the annual change in the wholesale price index) from the nominal interest rate. Non-forestry income in the supply equation was described by the household disposable income series from the National Accounts. Beginning-of-period forest inventory was unfortunately not available, and a proxy for it was calculated using the initial stock in 1960 and adding recursively the difference between annual interpolated forest growth and annual drain of wood. All nominal value series were deflated using either the production price index by industrial branches for input series or wholesale price index for the other series. Logarithmic transformations of aggregate time series data for the period 1960–1992 were used.

Prior to estimation, properties of the series were tested, because they determine the appropriate forms of models that can be used (e.g. Engle & Granger 1987, Johansen 1988, Johansen & Juselius 1990). Non-stationarity of time series was tested using augmented Dickey–Fuller (ADF) tests (Dickey & Fuller 1979) and the Perron test allowing for a one-time structural change in the series (Perron 1989).

Following the econometric approach of Hendry and Spanos (e.g. Hendry et al. 1988, Spanos 1990), we first estimated the statistical system for both sawlog and pulpwood prices and quantities to be a congruent representation of a data-generating process (DGP). The statistical model summarizes the sample information and ensures that the statistical assumptions underlying the model are valid for the data used. Theoretical models of supply and demand determine the variables to be included in the statistical model, but the dynamic specification is dictated by the data.

After this, a more parsimonious structural interpretation (in our case two separate supply and demand systems) was sought by introducing the zero restrictions from equations 1 and 2 of the theoretical model. The validity of the structural econometric model was judged by applying various misspecification tests (see Doornik & Hendry 1994). The supply and demand equations were estimated by recursive least-squares (RLS) in order to examine the stability of the parameters, and by two- and three-stage least-squares (2SLS, 3SLS). The stumpage price exogeneity was tested by comparing the difference between the price coefficients from the RLS and 2SLS estimations (Berndt 1991). The stability and forecasting performance of the models was studied by using parameters estimated for the whole period and for the post-oil crisis period, 1976–1992. For a detailed desription of the test statistics used, see e.g. Doornik & Hendry (1994).

RESULTS

Time series properties of the data in logarithmic form were examined prior to modelling. To save space we do not report the results for different unit root tests, but they are available from the authors. Based on experiments using lag specifications from zero to three lags in DF tests with constant and trend and the Perron specification DF test, we concluded that both sawlog and pulpwood stumpage prices and quantities traded were stationary at the 5% level. For labour costs and user costs in both industries, and for the households' disposable income and forest inventory variables, the test results suggested possible non-stationarity. Because the endogenous variables of the model (stumpage prices and quantities) are stationary, using an error-correction model, e.g. Engle–Granger two-step estimation, was not applicable. The number of observations was too small for reliable multivariate cointegration analysis (Johansen 1988, Johansen & Juselius 1990). Further, the estimation results for difference-form models, which would take into account the possible non-stationarity of some variables, did not produce significant changes in parameters, and the explanatory power of the models weakened in the absence of long-run information. Therefore, we could be sure only that the linear combination of the model's exogenous variables was stationary, i.e. that possibly integrated variables were also cointegrated with each other.

Traditionally, when the roundwood market has been disaggregated into sawlog and pulpwood markets, the cross-price effect, i.e. the effect of pulpwood (sawlog) price on sawlog (pulpwood) quantity, has been included in the supply equation so as to take into account the substitution effects in supply (e.g. Brännlund et al. 1985, Kuuluvainen et al. 1988). However, in our supply models, the cross-price effects on supply were not significant according to *t*-tests and were rejected by the *F*-test for omitted variables. Furthermore, because our pulpwood prices turned out to be directly proportional to sawlog prices during the period studied, thus reflecting similar cyclical fluctuations, we excluded the cross-price effect from the reported supply models for both sawlogs and pulpwood.

In the statistical or reduced form model, a one-lag price–quantity system was sufficient to produce a well-behaved error term for both markets (see Toppinen 1995). The structural econometric models were derived imposing zero restrictions from the theoretical supply and demand Eqs (1) and (2), i.e. output prices and prices for inputs other than wood were omitted from the supply models and the supply side determinants were omitted from the demand models. As the system overidentification tests favoured single equation techniques, 2SLS results are reported in Tables 1 and 2. Simultaneous equations estimation was justified because stumpage price exogeneity was rejected by *F*-tests for both sawlog supply and demand and also for pulpwood demand. Owing to large standard errors, these tests may, however, have low power. The restriction testing for homogeneity of degree zero in factor prices was not rejected by the Wald test in either sawlog or pulpwood demand.

Except for the demand for sawlogs in 1960–1992 and supply of pulpwood in 1976–1992, the statistically justified lag structure for stumpage prices could be derived using the adaptive expectations mechanism. Assuming that expectations are corrected adaptively, based on observed errors in past expectations, the expectations formation mechanism can be written as $\ln E_{t+1}c_{t+1} - \ln E_{t-1}c_t = \lambda(\ln c_t - \ln E_{t-1}c_t)$, where c is price, E is the expectations operator and λ is the adjustment parameter. This adaptive expectations formula, originating with Cagan (1956), can be shown to lead in an empirical specification including the present and lagged prices and the lagged endogenous variable (Brännlund 1988, p. 103). For sawlog demand over the whole period and pulpwood demand and supply in 1976–1992, the statistically valid model specifications seem to support regressive price expectations, where lagged prices directly represent the expected price level to which current prices are assumed to return in the future. However, as the economic theory is not as yet explicit concerning hypotheses on short-run adjustment processes, the observed dynamics may also be due to other adjustment processes affecting the actual data-generating process, and caution is advised in interpreting the results.

According to the estimation results, the elasticity of sawlog supply with respect to present sawlog price was positive, but not statistically significant and the absolute value of the elasticity was close to zero. Elasticity with respect to lagged sawlog price was large and negative, indicating a negative long-run effect. The effect of first differences of disposable income on sawlog supply was negative and significant at the 10% level. The effect of the first differences of timber inventory was positive, but the absolute size of the elasticity was difficult to interpret. The negative effect of the interest rate on sawlog supply indicates an imperfect capital market for the period 1960–1992. Contrary to our expectations, the short-run elasticity of sawlog demand with respect to stumpage price was positive and significant, whereas the long-run price elasticity was close to zero. The export price effect was carried through lagged prices, and the elasticity of lagged export price of sawnwood was 2.3. Neither wage cost nor capital user costs were found to be significant in sawlog demand.

Table 1. *Estimated elasticities of the two-stage least-squares (2SLS) sawlog model 1960–1992*

t-statistics in parenthesis below the coefficients

Independent variable: sawlog quantity	Supply 2SLS	Demand 2SLS
Constant	17.27	−14.73
	(3.20)	(−1.96)
Sawlog price	0.16	2.28
	(0.39)	(3.89)
Lagged sawlog price	−1.46	−2.23
	(−5.43)	(−5.64)
Lagged sawlog quantity	0.53	–
	(4.40)	–
Lagged change of sawlog quantity	–	0.13
	–	(2.29)
Lagged interest rate	−1.99	–
	(−2.39)	–
Difference of disposable income	−1.62	–
	(−1.73)	–
Difference of forest inventory	15.97	–
	(2.91)	–
Capital cost	–	0.22
	–	(0.42)
Wage cost	–	0.002
	–	(0.01)
Lagged sawnwood export price	–	2.34
	–	(2.29)
Coefficient of multiple determination, R^2	0.76	0.76
Durbin–Watson first order residual autocorrelation coefficient (DW)	1.80	1.56
Third-order residual autocorrelation test, F (RAC)	2.69	2.48
Heteroscedasticity LM[a]	1.11	0.06
Normality χ^2 (2)[b]	0.10	1.47
Validity of instruments χ^2 (I)[c]	1.77	5.28
Overidentification χ^2 (OI)[d]	7.97	8.57
Structural change Chow (1976)[e]	1.76	1.41
Forecasting Chow—F (4)[f]	1.10	0.08
Homogeneity of factor prices	–	0.69

[a] LM(ARCH) test is used for heteroscedasticity of residual term. [b] The normality test is the Jarque-Bera test for normal distribution of residual term. [c] χ^2 (I) is the validity test of instruments used in 2SLS. [d] χ^2 (OI) is the test for overidentification restrictions on the statistical model. [e] The Chow breakpoint test is used for structural change in the model at the sample midpoint (1976). [f] The Chow forecast test for out-of-sample one-period-a-head forecasts for 1989–1992.

The sawlog model passed diagnostic tests, e.g. for residual autocorrelation, heteroscedasticity and normality. The introduction of the nationwide price recommendation system in the late 1970s could be expected to have some effect on the stability of the models. However, the Chow test did not indicate structural change in the mid-1970s for the sawlog market, and the parameter variability in the model was small according to recursive estimations. The forecasting performance of the sawlog model for the years 1989–1992 was acceptable.

In the pulpwood supply equation, neither disposable income nor (negative) interest rate were significant, in contrast to the model of Hetemäki & Kuuluvainen (1992). The effect of pulpwood price was negative, but again the present price was not statistically significant. Pulpwood demand was less sensitive than sawnwood demand with respect to export price. The pulp export price had a positive and significant effect on the demand for pulpwood, as was expected. In pulp and paper industry production, labour input was found to be a technical substitute for pulpwood, as also in previous studies, e.g. by Hetemäki (1990) and Newman (1987).

The pulpwood supply equation did not pass the validity of instruments and overidentification model tests. Further, the Chow test statistics for structural change in 1976 were significant in the pulpwood supply and demand equations. Also stability analysis, i.e. recursive residuals (one step-ahead recursive forecasts) and recursive coefficients in the models indicated parameter variability in pulpwood models. The pulpwood supply equation also behaved poorly in forecasting tests.

Further, we estimated both the sawlog and pulpwood models with dummy variables, taking into ac-

Table 2. *Estimated elasticities of pulpwood model 1960–1992 (agreement denotes to supply and demand equation estimated with price agreement dummy as an additional regressor)*

t-statistics in parenthesis below the coefficients. Asterisk indicates rejection of null hypothesis. For the other symbols used, see footnote to Table 1

Independent variable: pulpwood quantity	Supply 2SLS	Supply (agreement)	Demand 2SLS	Demand (agreement)
Constant	−8.65	−3.41	−0.68	1.89
	(−2.00)	(−0.88)	(−0.49)	(0.87)
Pulpwood price	0.41	0.34	−0.04	0.14
	(2.06)	(2.01)	(0.44)	(−0.19)
Lagged pulpwood price	−0.99	−0.85	−0.79	−0.82
	(−6.21)	(−6.23)	(−3.85)	(−3.70)
Lagged pulpwood quantity	0.34	0.31	0.28	0.28
	(3.06)	(3.33)	(2.44)	(2.71)
Interest rate	−0.49	−0.14	–	–
	(−0.78)	(−0.26)	–	–
Forest inventory	2.20	1.28	–	–
	(2.02)	(1.35)	–	–
Disposable income	−0.09	−0.12	–	–
	(−0.37)	(−0.58)	–	–
Difference of capital cost			0.33	0.39
			(1.21)	(0.94)
Wage cost			0.37	0.19
			(1.51)	(4.52)
Difference of wood chip price			0.54	0.27
			(1.97)	(0.82)
Pulp export price			0.60	0.27
			(2.72)	(0.91)
Price agreement dummy			0.20	0.17
			(3.48)	(1.92)
R^2	0.75	0.83	0.75	0.81
DW	1.89	2.17	2.33	2.27
Autocorrelation F (RAC)	1.58	0.44	1.44	1.32
Heteroscedasticity LM	1.34	2.11	0.12	0.34
Normality χ^2 (2)	4.50	0.61	3.70	0.57
Validity of instruments χ^2 (I)	8.76*	3.45	2.55	2.15
Overidentification χ^2 (OI)	10.25*	3.76	2.29	2.59
Structural change Chow (1976)	3.54*	–	−5.96*	–
Forecasting Chow—F (4)	21.2*	2.10	1.20	1.70
Homogeneity of factor prices	–	–	1.04	0.19

count the existence of comprehensive price agreements (i.e. $D = 0$ for the years 1960–1978 and 1991–1992, and $D = 1$ for the years 1979–1990). The results indicated that the price agreements had increased the level of pulpwood supply and demand from private forests, but had no effect on either supply or demand for sawlogs (estimation results appear in Table 2). The diagnostic tests for the pulpwood supply model were also clearly better, with respect to validity of instruments and forecasting, when the dummy variable was included in the model.

The supply and demand models were also estimated separately for the periods 1960–1975 and 1976–1992. To save space, the former results are not reported here (see Toppinen 1995). For the period 1976–1992, positive long-run elasticities of supply were obtained for both sawlogs and pulpwood (Table 3). The long-run own-price elasticity of sawlog supply with respect to price was as high as 2.7. Also, the long-run elasticity of pulpwood supply with respect to pulpwood price was positive, but close to zero in absolute terms. Compared to the whole sample results, the effects of disposable income and the negative effect of the interest rate weakened while the price effects got stronger during the 1980s. This may be interpreted as

Table 3. *Sawlog and pulpwood demand and supply estimation results in* 1976–1992
t-statistics in parenthesis below the coefficients. For the symbols used, see footnote to Table 1

	Supply sawlog	Demand sawlog	Supply pulpwood	Demand pulpwood
Constant	−34.01	−17.61	−34.57	0.70
	(−0.80)	(−2.09)	(−1.66)	(0.27)
Sawlog or pulpwood price	4.02	2.43	2.18	0.72
	(1.90)	(2.13)	(3.27)	(1.29)
Lagged sawlog or pulpwood price	−2.22	−2.30	−2.03	−1.80
	(−2.81)	(−4.42)	(−5.39)	(−7.35)
Sawnwood or pulp export price	–	2.34	–	0.57
	–	(2.34)	–	(2.14)
Capital cost in sawmill industry or	–	0.71	–	1.21
difference of capital cost in pulp industry	–	(0.75)	–	(1.84)
Labour cost	–	–	–	0.54
	–	–	–	(3.89)
Lagged quantity	0.33	0.39	–	–
	(1.35)	(2.55)	–	–
Difference of interest rate	−1.92	–	–	–
	(−0.95)	–	–	–
Disposable income	−2.41	–	−2.16	–
	(−0.96)	–	(−1.30)	–
Forest inventory	7.47	–	8.46	–
	(0.87)	–	(1.60)	–
R^2	0.49	0.79	0.76	0.94
DW	1.91	1.96	2.87	2.64
F (RAC)	1.09	0.00	2.64	0.90
LM (ARCH)	2.89	0.68	0.32	0.46
Normality χ^2 (2)	2.74	0.45	1.63	0.84
Validity of instruments χ^2 (I)	0.59	0.61	0.38	5.48*
Overidentification χ^2 (OI)	2.67	1.18	2.58	7.88*
Chow F (4)	1.46	0.21	0.87	0.36

a reflection of deregulation of the capital markets during the 1980s in Finland.

DISCUSSION

We examined the possibility of reformulating short-run models of the supply and demand for sawlogs and pulpwood in Finland in light of recent developments in the roundwood markets. Prior to modelling, the non-stationarity and cointegration of the time series was tested. Dynamic error-correction models were not suitable for forecasting purposes due to the stationarity of the endogenous variables. The relationship between sawlog and pulpwood prices was found to be stable during the study period. Because the cross-price effects in the supply models were not statistically significant, they were omitted.

The estimation results confirmed our a priori expectations with some exceptions. In the sawlog demand an unexpected positive short-run price elasticity was obtained, whereas the long-run effect was close to zero. We surmised that the short-run effect was related to either correlation between lagged export price and sawlog price or na < ve formulation of export price or stumpage price expectations. The elasticity of the lagged export price of sawnwood was 2.3. This could partly reflect a liquidity effect of export incomes. Also the seasonal pattern of sawnwood export sales and raw materials purchases could explain this lag structure. However, the seasonal variation in trade diminished during the 1980s. During the estimation period 1976–1992 the current sawnwood price could be used in the sawlog demand model instead of the lagged one. In the sawlog supply model, the negative effect of disposable income on sawlog supply suggested an imperfect capital market, so that a transitory decrease in non-forestry income was compensated by selling more timber.

Pulpwood demand seemed to be less sensitive than sawnwood demand with respect to export price. The pulp export price had a positive and significant effect on the demand for pulpwood, whereas it was not present in the earlier model by Hetemäki & Kuuluvainen (1992). In pulp and paper industry production, labour input was found to be a substitute in production for the wood input, which confirms previous findings, e.g. of Newman (1987) and Hetemäki & Kuuluvainen (1992).

The effect of capital market liberalization can be seen in a reduction in the statistically significant factors affecting the supply of timber. Furthermore, our results indicated that the sensitivity of wood supply to stumpage price increased during the 1980s. A simple interpretation of this is that during the nationwide price agreements, market information was also carried through channels other than prices. According to estimation results from the model with the dummy variable for the years of recommended price agreements, the collective price negotiation system was found to have an effect via the pulpwood market. The agreement dummy was not significant in the sawlog supply or demand, but the absolute values of price effects on the supply of sawlogs increased considerably during the latter period. According to the estimation results, the pulpwood markets have experienced structural changes since the 1970s more distinctly than the sawlog markets. It can be concluded that forecasting short-run pulpwood market developments with pre-oil crises data may not be successful. However, even the price elasticities for the shorter period must be treated with caution when forecasting short-run behaviour of the markets in the 1990s, because nationwide recommended price agreements are no longer possible under the competition legislation of the European Union. Therefore, the usefulness of the estimated elasticities outside the nationwide price agreement period may be questioned.

To conclude, institutional changes seem to invalidate the use of annual observations in short-run forecasting in the Finnish timber market. This is due to the fact that there are too few annual observations under a given market structure to allow for reliable statistical inference. Thus future efforts to develop accurate short-run forecasting models should be based on quarterly or monthly data.

REFERENCES

Adams, D. & Haynes, R. 1980. The softwood timber assessment market model: structure, projections and policy simulations. Soc. Am. For. For. Sci. Monogr. 22: 64 pp.

Berndt, E. 1991. The Practice of Econometrics: Classic and Contemporary. 702 pp. Addison Wesley Publishing Co., Reading, Massachusetts. ISBN 0-201-17628-9.

Brännlund, R. 1988. The Swedish roundwood market. An econometric analysis. Swedish Agricultural University, Department of Forest Economics, Umeå. Rapport 82. 187 pp. ISBN 91-576-3436-X.

Brännlund, R., Johansson, P.-O. & Löfgren, K.-G. 1985. An Econometric Analysis of Aggregate Sawtimber and Pulpwood Supply in Sweden. For. Sci. 31: 595–606.

Cagan, P. 1956. The monetary dynamics of hyperinflation. *In* Studies in the quantity theory of money. Friedman, M. (ed.). University Chicago Press, Chicago.

Dickey, D. & Fuller, W. A. 1979. Distribution of the estimators for autoregressive time series with a unit root. J. Am. Stat. Assoc. 74: 427–431.

Doornik, J. & Hendry, D. 1994. PcFiml 8.0. Interactive econometric modelling of dynamic systems. 436 pp. Institute of Economics and Statistics University of Oxford, International Thomson Publishing, London. ISBN 1-850-32113-2.

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

Hetemäki, L. 1990. Factor substitution in the Finnish pulp and paper industry. Acta For. Fenn. 211: 87 pp. ISBN 951-40-1093-0.

Hetemäki, L. & Kuuluvainen, J. 1992. Incorporating data and theory in roundwood supply and demand estimation. Am. J. Agric. Econ. 74: 1010–1018.

Hendry, D., Neale, A, & Srba, F. 1988. Econometric analysis of small linear systems using PC-FIML. J. Economet. 38: 203–226.

Johansen, S. 1988. Statistical analysis of cointegrating vectors. J. Econ. Dyn. Control 12: 231–254.

Johansen, S. & Juselius, K. 1990. Maximum likelihood estimation and inference on cointegration—with applications to the demand for money. Oxford Bull. Econ. Stat. 52: 169–210.

Koskela, E. 1989. Forest taxation and timber supply under price uncertainty: credit rationing in the capital markets. For. Sci. 35: 160–172.

Kuuluvainen, J. 1990. Virtual price approach to short-term timber supply under credit rationing. J. Environ. Econ. Manag. 19: 109–126.

Kuuluvainen, J., Hetemäki, L., Ollonqvist, P., Ovaskainen, V., Pajuoja, H., Salo, J., Seppälä, H. & Tervo, M. 1988. The Finnish roundwood market: an econometric analysis. Finn. Econ. Pap. 1: 191–201.

Kuuluvainen, J., Karppinen, H. & Ovaskainen, V. 1996. Landowner objectives and nonindustrial private timber supply. For. Sci. 42: 300–309.

Murray, B. C. 1995. Measuring the oligopsony power with shadow prices: U.S. markets for pulpwood and sawlogs. Rev. Econ. Stat. LXXVII: 486–498.

Newman, D. 1987. An econometric analysis of the southern softwood stumpage market: 1950–80. For. Sci. 33: 932–945.

Perron, P. 1989. The Great Crash, the oil price shock, and the unit root hypothesis. Econometrica 57: 1361–1401.

Spanos, A. 1990. The simultaneous equations model revisited. J. Econometr. 44: 87–105.

Toppinen, A. 1995. Econometric forecasting model of the Finnish roundwood market. Licentiate thesis. University of Helsinki, Department of For. Economics, 83 pp.

II

Testing for Granger-Causality in the Finnish Roundwood Market

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The existence and direction of causal relationships between the time series for the Finnish roundwood market for the period 1960–1994 is tested. Using simple bivariate analysis, we found evidence that for both logs and pulpwood, the lagged prices are helpful in forecasting quantity for the next year, but not vice versa. Sawlog stumpage prices have significantly Granger-caused pulpwood prices over the business cycles, but the effect has diminished towards the present time. For quantities traded, the direction of causality was rather from pulpwood to sawlogs. The consistency of bivariate test results was checked by the Granger-causality tests within trivariate VAR-models for both markets, and the results were found to be fairly similar to bivariate tests. The price fluctuations in the international markets for forest products have been found to be carried to domestic wood markets dominantly via the pulpwood part of the market.

Keywords stumpage prices, roundwood market, Granger-causality, forecasting, time series analysis
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1 Introduction

The present paper reports on empirical testing of the existence of interdependencies between the key variables for the Finnish roundwood market. Motivation for the work is given by the need for developing short-term forecasting models for the Finnish wood market. Previous econometric studies of the sawlog and pulpwood markets in Finland include Kuuluvainen et al. (1988) and Hetemäki and Kuuluvainen (1992). Tervo (1986) studied structure and fluctuations of the aggregate roundwood market. However, none of these studies focused particularly on forecasting issues.

Although roundwood markets in different countries have been the topic of a number of economic studies, there are very few studies that explicitly test for causal effects. Buongiorno et al. (1985) considered testing for causality between lumber and stumpage prices and stumpage supply from the U.S. National Forests in 1962–84 and Uri and Boyd (1990) have researched the integration of four regional lumber markets in the U.S. by using causality tests. Considering the Finnish pulpwood market, Hetemäki and Kuuluvainen (1992) recognized causality running from pulpwood price to pulpwood quantity. However, they did not consider the sawlog part of the market, which accounts for about two thirds in total stumpage price earnings (Statistical yearbook of forestry 1996).

Following e.g. Brännlund et al. (1985) or Newman (1987), the disaggregation of the wood market into sawlog and pulpwood markets appears to be a good starting point for Finland as well. The setup for the market model for sawlogs and pulpwood can be found in Toppinen (1995) together with a more detailed description of recent changes in the market environment. It suffices to note here that we assume that a reasonable approximation of stumpage price determination in Finland is given by supply and demand factors, even though our study period includes an era of collective nationwide price recommendations (1978–1991) involving the Forest Industry Federation and the Federation of Forest Owners in Finland. Despite the price negotiations, there is evidence of market functioning since actual prices have not equaled recommended prices even during those years. Also, the negotiated stumpage prices were based to a great extent on export price developments for forest industry products, which are exogenous to producers in a small open economy such as Finland.

In this study Granger's direct causality test (1969) is used to investigate the bivariate causal ordering and possible feedback between the key variables of the roundwood market, i.e. stumpage prices and quantities and export prices of forest industry products. Because two-thirds of the sawnwood production and close to 90 percent of paper production are currently being exported from Finland, the export price and demand fluctuations represent the main source of external shocks to the Finnish forest sector. Implications of the results for further modelling and forecasting of Finnish roundwood market are discussed briefly.

2 Data and Methods

In modelling of the roundwood market in Finland, the most interesting causal relationships are those between prices and quantities of wood. As wood prices, we used stumpage prices since currently about 70 percent of the total volume of sawlog and pulpwood purchased from private forests originates from stumpage sales. Secondly, delivery prices (roadside prices) for logs and pulpwood fluctuate very much like to stumpage prices, but are less comparable to each other over the years.

As prices for forest industry products, we used export prices of coniferous sawnwood and prices of sulphate pulp. The link between sawnwood and sawlog prices is natural, since sawlogs are the main raw material input to the sawmill industry. For the derived demand for pulpwood, we have chosen pulp demand. Although the share of exports in pulp produced in Finland is currently small due to the integrated production of pulp and paper, pulp prices are clearly reflected in the prices of paper and paperboard products. Furthermore, due to strongly increased product diversification in the paper industry, it would be difficult to find a paper product that would remain as a homogenous product group during the whole study period, i.e. over three decades.

Annual stumpage price series for the felling years 1959/60 to 1993/94 were used for coniferous sawlogs (PSL) and pulpwood (PPW). The respective quantities purchased from private forests in millions of cubic meters were denoted as QSL and QPW. Data on stumpage prices and roundwood quantities were obtained from the Forestry Statistics of Finland. For export price variables, we used export unit value for coniferous sawnwood (SX) and sulphate pulp (CPX) as obtained from the Finnish customs statistics (FOB prices in Finnish marks). Since stumpage prices and quantities are not reported for calendar years, we had to simply assume, as in previous studies, that felling year 1993/94 is comparable to calendar year 1994 etc. Real prices were used, so that nominal prices were deflated by the wholesale price index, which is available in Official Statistics for Finland (Source: Statistics Finland).

To study the causal relationships between the time series, Granger-causality tests (Granger

1969) were calculated between stumpage prices and export prices of forest industry products and with respect to quantities of roundwood traded. In fact, Granger-causality tests can be better interpreted testing predictability between certain variables of interest. If knowledge of one time series results in smaller error variance in predicting another series than would result from using only the past information of another series, then the first time series is said to Granger-cause the other one.

Essentially, bivariate Granger-causality testing involves the use of F-tests to determine whether lagged values of a variable, say X, have any statistically significant contribution in explaining Y_t in addition to lagged Y_{t-j}. Thus, one is testing the null hypothesis $c_j = 0$ ($j = 1,\ldots K$) in

$$Y_t = a + \sum_{j=1}^{K} b_j Y_{t-j} + \sum_{j=1}^{K} c_j X_{t-j} + u_t \qquad (1)$$

where u_t is assumed to be a well-behaved white noise error term (Granger and Newbold 1986).

The procedure is applied in the opposite direction to test the causality from Y to X. If Granger-causality proceeds in both directions simultaneously, there is feedback between the variables. When comparing asymptotic behaviour of eight different causality tests, Geweke et al. (1983) recommended the use of this regression-based F-test because it was found to perform well also in small samples.

In using the bivariate causality tests, it is not possible to rule out that results could be sensitive to the effects from omitted variables. For checking the consistency of bivariate results we calculated the same tests using multivariate VAR-models. In order to avoid problems concerning degrees of freedom, we chose to use separate VAR-systems for both pulpwood and sawlog markets. Restrictions testing Granger-causality were tested using the Wald test (see e.g. Greene 1993).

In general, time series that reflect forward-looking behaviour are often found to be predictors of economic time series. Instantaneous causality tests using X_t as an additional regressor, are sometimes used together with the ordinary Granger-causality test (e.g. Buongiorno et al. 1985). However, the logical conceptual framework for testing instantaneous causality has been questioned (Granger 1988). Instantaneous causality may be related to the small time delay between cause and effect compared to the time interval for which the data are collected, or to the case when truly causal variables are not included in the information set. In our case, if stumpage prices and quantities were determined simultaneously, an instantaneous causality test based on least squares estimation would also contain simultaneous equation bias. Due to these considerations, we did not test for instantaneous causality (see, however, Toppinen 1995).

The Granger-causality test is based on basic assumptions such as that individual variables are (weakly covariance) stationary and that there is no residual autocorrelation in the causality test regression. Sims et al. (1990) have shown that if the time series are nonstationary and contain unit roots, non-standard distributions should be applied in testing. Especially in the case where nonstationary time series are at the same time cointegrated, i.e. they exhibit similar co-movement over time, it is possible to test for non-causality with linear restriction in cointegration space, for example with Johansen's maximum likelihood approach (Johansen and Juselius 1992, Mosconi and Giannini 1992).

In the empirical section, we thus first tested for the existence of unit roots in all six variables by using both the standard Augmented Dickey Fuller test (hereafter ADF) and the Phillips-Perron version of ADF-test (Dickey and Fuller 1979, Phillips and Perron 1988). The null hypothesis for the tests is non-stationarity of a variable.

3 Results

Historically there have been strong cyclical fluctuations in stumpage prices and quantities in Finland (Fig. 1), originating mainly from the international markets for forest industry products. During the 1980s, the stumpage price recommendation system stabilized price fluctuations in Finland but not quantity fluctuations. In real terms, the sawlog price is at the same level in the 1990s as during the 1960s, while both the pulp-

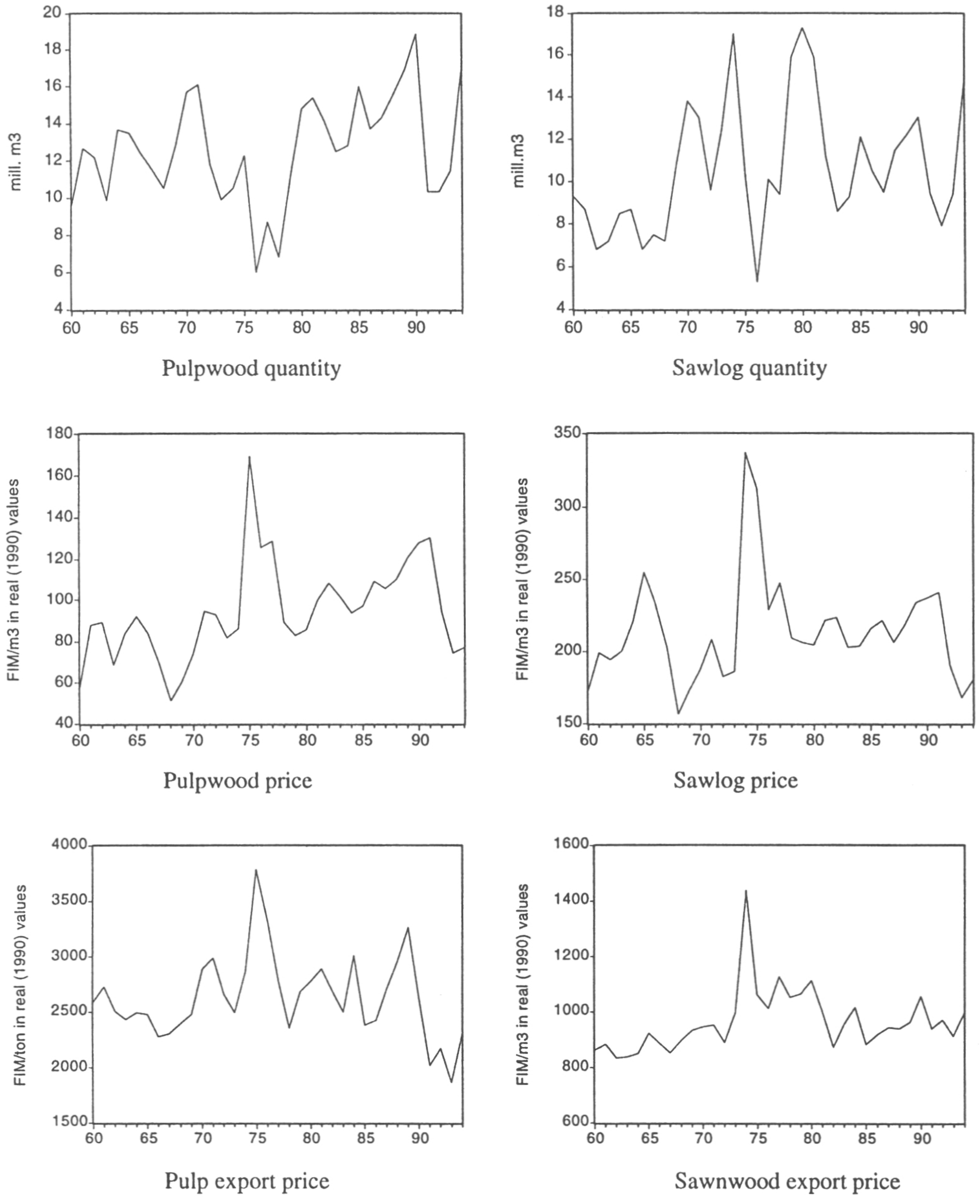

Fig. 1. Graphs of the variables in the study.

Table 1. Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) tests for the unit roots in individual time series. * indicates significance at 10 % level, ** at 5 % level and *** at 1 % level in the two tests.

	ADF-test (p = number of lags, constant term included)		PP-test (p = lag truncation)	
PPW Pulpwood price	−2.93*	(p = 0)	−3.07*	(p = 2)
PSL Sawlog price	−3.41**	(p = 1)	−3.30**	(p = 1)
QPW Pulpwood quantity	−3.38**	(p = 0)	−3.52**	(p = 2)
QSL Sawlog quantity	−3.71***	(p = 1)	−2.99**	(p = 2)
CPX Pulp export price	−3.39**	(p = 1)	−2.95**	(p = 2)
SX Sawnwood export price	−3.37**	(p = 0)	−3.04**	(p = 2)

Table 2. Granger-causality tests for period 1960–94. F-test values are for two lag models with the null hypothesis of non-causality, probability values given in the parentheses.

	F-statistic F(2,31)		F-statistic F(2,31)
PPW→PSL	1.11 (0.34)	PSL→PPW	**8.03 (0.001)**
PSL→QSL	**12.5 (0.0001)**	QSL→PSL	0.20 (0.82)
PPW→QPW	**9.79 (0.001)**	QPW→PPW	0.27 (0.76)
QSL→QPW	2.68 (0.09)	QPW→QSL	**3.67 (0.04)**
QSL→PPW	**5.50 (0.001)**	PPW→QSL	**12.96 (0.0001)**
QPW→PSL	0.59 (0.56)	PSL→QPW	**6.98 (0.03)**
SX→PSL	1.34 (0.28)	PSL→SX	1.90 (0.17)
SX→QSL	1.02 (0.98)	QSL→SX	0.12 (0.88)
CPX→PPW	2.87 (0.07)	PPW→CPX	0.67 (0.51)
CPX→QPW	**3.89 (0.03)**	QPW→CPX	0.43 (0.65)

wood price and quantity variables exhibit a slightly rising trend.

Before proceeding to the Granger-causality test, we checked the assumption that the time series are stationary. Both the Augmented Dickey Fuller and Phillips-Perron tests indicated that non-stationarity should not be a problem in our data (Table 1). The null hypothesis of unit root could be rejected at the 5 percent level for all the time series except for pulpwood stumpage price, for which it was rejected at the 10 percent level. We proceeded under the assumption that all our variables are stationary, and used the levels of logarithmic variables in testing for causality.

The Granger-causality tests were performed using lags of 1 to 3 years in the test equations. In general, the test results were robust for different lags. The F-form of the Lagrange-Multiplier test, which is valid for systems with lagged dependent variables (see e.g. Greene 1993), was used to examine that there was no autocorrelation in the residual term of the test equation. Since there was in general no indication of residual autocorrelation left in the regression equation with $j = 2$, we present in Table 2 the results for the causality tests using two lags.

The results from Granger-causality tests indicated significant one-way causality from both stumpage prices to roundwood quantities traded, but feedback from traded quantities to their own prices was absent. Furthermore, there appeared to be linkages between the two wood markets: the sawlog stumpage price helped to forecast the pulpwood stumpage price over autoregressive pulpwood price forecasts. On the other hand, with the two wood quantities, the causality was running from pulpwood quantities to sawlog quantities. Sawlog quantity helped to forecast the pulpwood stumpage price, which could be due to the fact that business cycles in the sawmilling industry have often been leading the fluctuations in the pulp and paper industry.

Table 3. Granger-causality tests for the exclusion of variables in rows from VAR (p = 3, k = 2) model for sawlog market, with probablity values given in the parentheses.

	1960–94 Granger-causality to			1960–77 Granger-causality to			1978–1994 Granger-causality to		
	PSL	QSL	SX	PSL	QSL	SX	PSL	QSL	SX
PSL	–	**41.80**	4.78	–	**22.59**	**7.14**	–	**11.73**	2.03
		(0.00)	(0.09)		**(0.00)**	**(0.03)**		**(0.02)**	(0.36)
QSL	0.38	–	1.34	0.10	–	1.98	1.86	–	2.87
	(0.83)		(0.51)	(0.95)		(0.37)	(0.39)		(0.36)
SX	2.48	**9.83**	–	1.84	**10.22**	–	1.81	0.95	–
	(0.29)	**(0.01)**		(0.40)	**(0.01)**		(0.41)	(0.62)	

Table 4. Granger-causality tests the exclusion of variables in rows from VAR (p = 3, k = 2) model for pulpwood market, with probablity values given in the parentheses.

	1960–94 Granger-causality to			1960–77 Granger-causality to			1978–1994 Granger-causality to		
	PPW	QPW	CPX	PPW	QPW	CPX	PPW	QPW	CPX
PPW	–	**12.78**	2.22	–	**13.64**	0.76	–	**9.82**	4.24
		(0.01)	(0.33)		**(0.01)**	(0.68)		**(0.01)**	(0.12)
QPW	1.30	–	1.76	2.40	–	1.11	**25.60**	–	2.09
	(0.52)		(0.41)	(0.30)		(0.57)	**(0.01)**		(0.35)
CPX	**6.28**	3.17	–	4.52	3.23	–	**10.7**	**6.74**	–
	(0.04)	(0.20)		(0.10)	(0.20)		**(0.01)**	**(0.03)**	

Quite surprisingly, lagged export prices of forest products did not contribute significantly in explaining stumpage prices of either sawlogs or pulpwood. However, pulp export prices were found to significantly cause pulpwood quantity. Our interpretation to this result is that the pulpwood market is the channel through which the shocks in the export markets have been carried to domestic wood markets.

In order to take account the possible problems arising from omitted variables in bivariate tests, we tested for the Granger-causality in both submarkets also using three variable VAR-systems. Secondly, as a check to whether the results for causality tests are sensitive to the specific data period, we performed the same set of tests with the sample period divided into two subperiods. Results for the total sample and for subperiods 1960–77 and 1978–94 are presented in Tables 3 and 4.

Significant causality from stumpage prices to quantities was detected, but no feedback effect was found for the period 1960–94, when the VAR-models were used. However, during the latter period in 1978–94, two-sided causality was detected between pulpwood stumpage prices and quantities. Also, Granger-causality running from pulp export prices to pulpwood stumpage prices was detected in 1960–1994. This effect was even more clearly present in the market during the latter half of the sample period. In addition, the pulp price was found to help in forecasting the pulpwood quantity in 1978–94.

In sawlog market system, stumpage prices were found to cause quantities throughout the whole period. However, the other causal relations in the sawlog system were again less in accordance what could be expected. Sawnwood export price was found to Granger-cause sawlog quantity, but the effect was no longer present during the second half of the sample. Quite unexpectedly, the sawlog quantity was found to Granger-cause sawnwood price, but only in the first half of the sample.

4 Discussion

In this study, direction and significance of Granger-causality were examined in the Finnish stumpage market. The results are useful as background information for building econometric short-term forecasting models for the roundwood market. However, the shortcoming of the approach is that it does not measure the relative strength of the relationship. As such, the causality tests should be rather viewed as tests of whether one variable helps in forecasting another variable rather than as strict tests of causation. One-way causality from stumpage price to quantity is not, however, sufficient evidence for the use of least squares estimation in behavioral models, since Granger non-causality does not test simultaneity. Despite the fact that we used three variable VAR-models to check the consistency of bivariate causality tests, possible effects due to omitted variables should be borne in mind.

Disaggregation of the stumpage market into two submarkets enabled us to study the interdependencies between the two main assortments, i.e. sawlogs and pulpwood. Sawlog price was found to cause pulpwood price, but the effect weakened towards the present time. For both sawlogs and pulpwood, there was evidence of one-way causality from stumpage prices to wood quantities.

The Granger-causality tests indicated relatively weak causality running from sawnwood export markets to sawlog markets. The effects were more clearly present in the pulpwood part of the market, where Granger-causality from pulp prices to both pulpwood prices and quantities was found in period 1978–94. One explanation for the lack of strong causality from export prices to stumpage market could be found in the rough aggregation of the stumpage market into sawlog and pulpwood sectors, while in fact different wood species in the two wood assortments are used for certain differentiated products, and are not perfect substitutes for each other.

Also, some changes in causality patterns were revealed in comparing the two subperiods, i.e. 1960–77 and 1978–94. For example, two-sided causality, i.e. feedback between the price and quantity of pulpwood in the period 1978–94 was found. This indicates that the dynamics of the pulpwood market probably have changed during the study period. One plausible explanation for this could be the stumpage price recommendation system, which was in effect during most of the second period. However, studying this phenomenon explicitly requires other econometric tools than used in this paper, and has to be left for another study.

Due to changes in causality patterns over time, there may also be problems in obtaining stable parameter estimates for demand and supply models by using data that extends from the 1960s to the mid-1990s. Consequently, the development of short-term forecasting models should perhaps be directed towards the use of data covering shorter time spans and higher frequency, i.e. quarterly or monthly data. In this way we could also hope to learn more about the short-run dynamics between the markets for forest products and roundwood in Finland.

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References

Brännlund, R., Johansson, P-O. & Löfgren, K-G. 1985. An econometric analysis of aggregate sawtimber and pulpwood supply in Sweden. Forest Science 31: 595–606.

Buongiorno, J., Bark, S. & Brannman, L. 1985. Volume offered and wood prices: a causality test for National Forests. Forest Science 31: 405–414.

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.

Geweke, J., Meese, R. & Dent, W. 1983. Comparing alternative tests of causality in temporal systems. Analytic results and experimental evidence. Journal of Econometrics 21: 161–194.

Granger, C.W.J. 1969. Investigating causal relations by econometric models and cross-spectral methods. Econometrica 37: 424–438.

— 1988. Some recent developments in a concept of causality. Journal of Econometrics 39: 199–211.

— & Newbold, P. 1986. Forecasting economic time series. Academic Press. 316 p.

Greene, W. 1993. Econometric analysis. MacMillan. 791 p. ISBN 0-02-346391-0.

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

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.

Mosconi, R. & Giannini, C. 1992. Non-causality in cointegrated systems: representation, estimation and testing. Oxford Bulletin of Economics and Statistics 54: 399–417.

Newman, D. 1987. An econometric analysis of the Southern softwood stumpage market: 1950–80. Forest Science 33: 932–945.

Phillips, P. & Perron, P. 1988. Testing for a unit root in time series regression. Biometrika 75: 335–346.

Sims, C., Stock, J.H. & Watson, M. 1990. Inference in linear time series models with some unit roots. Econometrica 58: 113–144.

Statistical Yearbook of Forestry 1996. The Finnish Forest Research Institute. ISBN 951-40-1537-1. 352 p.

Tervo, M. 1986. Suomen raakapuumarkkinoiden rakenne ja vaihtelut. Summary: Structure and fluctuations of the Finnish roundwood markets. Communicationes Instituti Forestalis Fenniae 137. 66 p.

Toppinen, A. 1995. Econometric forecasting model of the Finnish roundwood market. Licentiate thesis. University of Helsinki, Department of Forest Economics. 83 p. + appendices.

Uri, N. & Boyd, R. 1990. Considerations on modelling the market for softwood lumber in the United States. Forest Science 36: 680–692.

Total of 18 references

III

TESTING FOR OLIGOPSONY POWER IN THE FINNISH WOOD MARKET

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ABSTRACT

In this study we test for oligopsony power of the pulp industry over the Finnish pulpwood and wood chip markets using the method introduced by Appelbaum. The method applies duality to derive a factor demand system from which the markdown of the pulpwood market price from the value of its marginal product is statistically estimated. Our empirical estimates assuming constant market power suggest that the pulpwood market in Finland has on the average been competitive during the period 1965–94. However, some evidence is found that wood chips purchased from sawmills have been priced below the value of their marginal product. This result is intuitively plausible due to the lack of countervailing power of the sawmilling industry as compared to suppliers of roundwood in the pulpwood market.

Keywords: pulp industry, pulpwood market, wood chips, oligopsony power, Finland

INTRODUCTION

In recent decades both stumpage prices and wood quantities in the Finnish roundwood market have fluctuated widely over the business cycle. Between 1978 and 1991 the stumpage prices were subject to nationwide collective bargaining system including representative organisations of the forest industry and private forest owners to set price recommendations for each felling season. Due to developments in the economic environment, more precisely the new competition law in 1992 and the Finnish membership in the EU in 1995, this negotiation system was prohibited. The market is characterized by a pronounced structural asymmetry, i.e. a small number of wood buyers in contrast to the over 300 000 nonindustrial private forest owners. Buyer concentration has increased due to mergers and acquisitions in the forest industry, especially in the last decade. Currently the three largest buyers dominate both the pulpwood and sawlog markets. The sawlog market is however characterized by a competitive fringe of numerous small sawmills.

Due to a small number of wood buyers, the Finnish wood market can be suspected of being imperfectly competitive. In spite of this, most econometric models of Finnish sawlog and pulpwood markets assuming competitive behaviour have described the market quite well (see e.g. Kuuluvainen et al. 1988, Hetemäki and Kuuluvainen 1992, Toppinen and Kuuluvainen 1997), although direct empirical evidence on testing the competitive market assumption is by and large nonexistent. In this paper we aim to fill this gap by modelling the Finnish pulpwood market as an oligopsony, *i.e.* a market with few buyers and many sellers.

In an oligopsony wood market, the buyer side may have market power over the suppliers of wood, resulting in a wood price level lower than that in a competitive wood market. Consequently, the wood buyers would gain a positive markup (or actually markdown, since we are dealing with an input market distortion) with the value of the marginal product for wood exceeding its market price. If buyers act collectively as a purchasing cartel, the market could even function as a monopsony. If there is oligopsony power in the pulpwood part of the market, it could mean a welfare transfer from suppliers of wood to pulp industry. It could also have an effect on the sizes of different wood using industries.

The contribution of this paper is the explicit testing of a potential deviation from competitive pricing in the wood input markets of Finnish pulp industry. Using the method introduced by Appelbaum (1979, 1982) and further developed by Atkinson and Kerkvliet (1989) and Bergman and Brännlund (1995), we apply duality to derive a factor demand system from which the markdown of the wood price from the value of its marginal product is statistically estimated. The factor demand system estimated in this study is based on a flexible functional form. In this respect, the paper can also be seen as an extension of Hetemäki's (1990) factor demand model for the Finnish pulp and paper industry, in which the wood input price was treated as an industry parameter. It should be noted that since we deal with the aggregate market and annual time series data, our results can say nothing about possible deviations from competitive wood pricing at the local level or over time periods shorter than a year.

THEORETICAL BACKGROUND AND PREVIOUS STUDIES

The theoretical framework for this study has been presented in the industrial organization literature (see e.g. Tirole 1988). Before the 1980s, the dominant approach was the structure-conduct-performance paradigm (SCPP), which tried to establish a direct link from industry structure to conduct, so that the level of competition could be implied by an industry's structural features. However, the SCPP was criticized later on because the relationship between industry structure and conduct is not unambiguously predicted by the theory of imperfect competition, e.g. high concentration in an industry does not necessarily imply noncompetitive behaviour. With the current methodology of the new empirical industrial organization (NEIO), the existence of market power can be studied more rigorously than before.

In NEIO, the degree of competition is typically analysed via the estimation of conjectural elasticities. These elasticities are computed as

$$(1) \qquad \theta^i = (\partial Q/\partial q^i)(q^i/Q),$$

where Q denotes industry output (or demand for oligopsonistic input) and q^i is the output (input) of i'th firm. θ^i measures the firm's expectation of the industry output change in response to its output change or alternatively, it can be simply interpreted as an index of market power. A comprehensive structural model for estimating the degree of market power in oligopolistic markets was introduced in Appelbaum (1982), and this method can be applied to input markets as well.

Numerous empirical applications of estimation and testing of market power can be found. Bresnahan (1989) and Slade (1995) provide surveys of these studies. Examples of studies that consider market power in output markets are Appelbaum (1982) and Bernstein and Mohnen (1991) for manufacturing industries, and Schroeter (1988) and Schroeter and Azzam (1990) for agricultural product markets. Input market distortions are considered e.g. by Just and Chern (1980), Bergman and Brännlund (1995), and Murray (1995), of which the latter two consider wood markets. Applications involving both input and output markets include Atkinson and Kerkvliet (1989) for the U.S. electrical utility industry, Wann and

Sexton (1992) for the California food industry, and Bernstein (1992) for the Canadian forest industries.

Bergman and Brännlund (1995) tested the oligopsony hypothesis for the Swedish pulpwood market, and their empirical results suggested a noncompetitive pulpwood market. Estimates of a strongly time-varying conjectural elasticity term in Bergman and Brännlund indicated an unstable cartel situation with phases of industry cartel under weak pulp markets and perfect competition under strong pulp markets.

Murray (1995) studied market power in both the pulpwood and sawlog markets in the U.S. He used a more restrictive approach modelling wood as a quasi-fixed factor, so that the shadow prices of the wood input could be estimated from a flexible-form profit function. His results suggested that the U.S. pulpwood market as a whole is more oligopsonistic than the sawlog market, although both markets were closer to perfect competition than to monopsony. In contrast to the two above-mentioned wood market studies, Bernstein (1992) accounted for capital adjustment costs in the Canadian sawmill and pulp and paper industries. Competitive behaviour was not rejected in any of the input or output markets of sawnwood or paper products.

THE MODEL AND ECONOMETRIC SPECIFICATION

Let us consider an individual firm in an n-firm oligopsonistic industry. Following notation in Bergman and Brännlund (1995), we write the twice continuously differentiable production function of firm i as

(2) $q^i = f(x^i_m, \tilde{x}^i)$,

where q^i is the firm's output quantity, $\tilde{x}^i$ is a vector of inputs with a parametric price vector $\tilde{w}$, and x^i_m is the input of factor *m* which is used only by the firm and its rivals. Assume that for input *m* the industry faces an inverse supply function

(3) $w_m = w_m(x_m, y)$,

where w_m is the price, x_m is supply $(\partial w_m/\partial x_m > 0)$, and *y* a vector of exogenous variables affecting the supply. In equilibrium, the supply x_m equals the industry's demand for that input. Let us assume that the firm maximizes its profit by choosing inputs x^i_m and $\tilde{x}^i$. Denoting the output price by w_p, the problem of firm *i* is:

(4) $Max_{x^i_m, \tilde{x}^i} \; w_p f(x^i_m, \tilde{x}^i) - w_m(x_m, y)x^i_m - \tilde{w}^T \tilde{x}^i$.

The optimality condition for profit maximization requires that the marginal product value of an input is equal to the perceived marginal cost of an input. For inputs with parametric price, this yields the equation

(5) $w_p \nabla_{\tilde{x}^i} f(x^i_m, \tilde{x}^i) = \tilde{w}$.

Assume that the firm realizes that since its use of input *m*, x^i_m, forms an important part of the total demand for the input, x_m, its input decision has an impact on price w_m. Let us denote the supply elasticity of the input price $(\partial w_m/\partial x_m)(x_m/w_m)$ by γ. Firm *i* may also conjecture that its input decision affects its rivals' input decisions. Let us denote this conjectural elasticity $(\partial x_m/\partial$

$x^i_m)(x^i_m/x_m)$ by θ^i. For a monopsonist, θ^i equals one, and for a firm that takes input price as given θ^i equals zero. Using the notation above, we can write the optimality condition for input demand x^i_m as

$$(6) \qquad w_p \partial f / \partial x^i_m = w_m(1+\theta^i \gamma) .$$

Due to a lack of data on individual firms, we must make some restrictive assumptions to enable aggregation of the firms in order to perform our analysis using industry-level data. One possibility is to assume that θ^i is the same for all the firms, so that all the firms face identical marginal prices. On the other hand, if we assume that the marginal product of input *m* is the same for all the *n* firms in the industry, then equation (6) implies that in equilibrium θ^i is the same for all the firms. We will make the former assumption, and denote the common conjectural variations parameter by θ. Using the equilibrium values for inputs and outputs, the industry shadow price variable profit function, Π, can be expressed as:

$$(7) \qquad \begin{aligned} &\Pi = w_p \cdot q(w_p, w_m(1+\theta\gamma), \tilde{w}) - w_m(1+\theta\gamma) \cdot x_m(w_p, w_m(1+\theta\gamma), \tilde{w}) \\ &- \tilde{w}\tilde{x}(w_p, w_m(1+\theta\gamma), \tilde{w}), \end{aligned}$$

where *q(.)* is the industry equilibrium output, and x_m and $\tilde{x}$ are the industry equilibrium inputs with (shadow) prices $w_m(1+\theta\gamma)$ and $\tilde{w}$ respectively. Applying Hotelling's Lemma in terms of shadow prices to equation (7), the output supply and the negative of input demand equations for the industry can be solved respectively as[1]

[1] Note that by replacing the actual prices in the initial maximum value profit function by the respective shadow prices, we get a maximum value profit function for the competitive industry that optimises with respect to the parametric shadow prices. At the point of the oligopsonistic industry's equilibrium, with price

(8) $$\frac{\partial \Pi}{\partial w_p} = q(w_p, w_m(1+\theta\gamma), \tilde{w})$$

(9) $$\frac{\partial \Pi}{\partial w_m(1+\theta\gamma)} = -x_m(w_p, w_m(1+\theta\gamma), \tilde{w})$$

(10) $$\nabla_{\tilde{w}} \Pi = -\tilde{x}(w_p, w_m(1+\theta\gamma), \tilde{w}).$$

In the econometric application we assume that the Finnish pulp industry uses two variable inputs, wood and labour, together with a quasi-fixed capital input in order to produce pulp, which is sold in competitive world markets. This framework allows for the possibility that the industry is not in long-run equilibrium. To account for technological change, time enters as a fixed input equations to be estimated. We based the model on a generalized Leontief (GL) profit function, which is a flexible functional form. This form allows us to avoid placing *a priori* constraints on the second derivatives of the profit function.

Let Z be an *n*-vector of the (quasi) fixed inputs and w^s an *m*-vector of *shadow* prices for output and variable inputs. Assuming a noncompetitively priced wood input, the shadow price of wood accommodates the markdown term *(1 + γθ),* where θ denotes the industry conjectural variations elasticity and γ denotes the supply elasticity of the wood price. For the other inputs and for the output, shadow prices equal market price. The chosen GL specification for the industrial shadow price variable profit function, $\Pi(w^s, Z)$, is

(11) $$\Pi(w^s, Z) = \sum_i^m \sum_j^m \beta_{ij}(w_i^s w_j^s)^{0.5} + \sum_i^n \sum_j^n \mu_{ij} Z_i Z_j + \sum_i^m \sum_j^n \phi_{ij} w_i^s Z_j,$$

$w_m^*(1+\theta^i\gamma)$ for the oligopsonistic input, the output and input levels chosen by a competitive industry are identical to those chosen by a noncompetitive industry facing an input price equal to w_m^*.

where β_{ij}, μ_{ij}, ϕ_{ij}, as well as the parameters γ and θ in the shadow price of wood, are estimated. For symmetry of the profit function, we impose the restrictions $\beta_{ij}=\beta_{ji}$ and $\phi_{ij}=\phi_{ji}$.

The shadow profit defined in Equation (11) may not be observed, but applying Hotelling's Lemma on shadow prices, we obtain output supply equation q and input demand equations for variable factors x_i.

$$(12) \qquad q=\sum_j^m \beta_{qj}(w_j^s / w_q^s)^{0.5}+\sum_j^n \phi_{qj}Z_j$$

$$(13) \qquad -x_i=\sum_j^m \beta_{ij}(w_j^s / w_i^s)^{0.5}+\sum_j^n \phi_{ij}Z_j .$$

Assuming roundwood input to be freely adjustable, the model consists of equation (12) for pulp output and equations (13) for wood and labour input. Because our purpose was to test the pricing rule, the markdown term for the wood price $(1 + \gamma\theta)$ was treated as a single parameter, χ, in our empirical model. The measure of actual oligopsony power, which can also be interpreted as the input market counterpart to the Lerner index, L, can be calculated from the estimate for χ as $\chi=1 + \theta\gamma$ so that we get $L\equiv\chi-1=\gamma\theta$.

Note that if the factor demand system is estimated simultaneously with the wood supply equation (3), it is possible to separate the supply elasticity of wood price, γ, from the conjectural elasticity term, θ. Because of a lack of data, this procedure could not be used for modelling the supply of wood imports or wood chips coming from the sawmilling industry, of which both are important raw material sources for the Finnish pulp industry. For domestic pulpwood, simultaneous estimation of the supply elasticity was attempted, but due to the wrong signs for the pulpwood supply elasticity estimates, this approach could not be used. However, it is justifiable to assume that the supply elasticities of wood input are finite since earlier roundwood market studies suggest that the elasticity of the stumpage price of pulpwood with respect to supply (i.e. the inverse price elasticity) lies between one and two (e.g. Kuuluvainen et al. 1988, Toppinen and Kuuluvainen 1997). Therefore, an estimate for χ that is greater than one indicates deviation from competitive wood pricing.

DATA

The model was estimated using annual data for Finland for the period from 1965 to 1994. The wood input of the pulp industry consists mainly of three different components; private nonindustrial forests, imported pulpwood and wood chips purchased from the sawmilling industry. Imports of pulpwood currently account for roughly one sixth of the total consumption of industrial roundwood in Finland. During the study period the average share of wood chips in total wood input for pulp production has been close to one fifth. However, the market for wood chips is not well defined, as a major part of chips are obtained as a by-product from sawmills owned by the companies that also produce pulp. The availability of residual wood varies annually, depending on business conditions in the sawmilling industry, which do not always coincide with business cycles in the pulp industry. Moreover, wood chips do not allow for a long storage period before pulping, whereas the wood buyer in the pulpwood stumpage market can postpone felling up to two years after purchasing the wood. Although wood chips are close substitutes for roundwood, differences in the quality of two inputs in pulp production is an open question.

All the three types of wood, i.e. wood chips, domestic pulpwood and imported pulpwood, have their own unique price developments during the study period. The cost of domestic roundwood has always exceeded the price of wood chips, while price differences between domestic and imported pulpwood are less pronounced. Price difference between wood and chips may be due to the fact that the inputs are not perfect substitutes or that the inputs differ in other respects that may affect the price, e.g. availability and terms of trade. The differences may also be a sign of imperfectly competitive markets, with suppliers being in different positions in negotiating vis-a-vis over the prices of their products.

The domestic roundwood price that we used is the value of domestic pulpwood input in the pulp and paper industry divided by the domestic pulpwood quantity, i.e. the mill price. This pulpwood mill price consists of a rather highly variable stumpage price component and a relatively stable harvesting and transportation cost component. The unit price of imported pulpwood (CIF) is the value of imports divided by the quantity of imports. For wood chips, no actual prices were available. Therefore we used the recommended price for wood chips at Kotka harbour up to the year 1986 (from Hetemäki 1990), and the price reported by a representative forest industry company thereafter. The firms in the forest industry are assumed to use market prices as a basis for their internal transfers of wood and chips. The low quality of the wood chip price data must be borne in mind when comparing results from alternative models.

The pulp price is the quantity-weighted export price (FOB) of mechanical and chemical pulp. The measure of pulp quantity is the sum of the Finnish output of mechanical and chemical wood pulp. The labour input is the total number of working hours in the pulp industry provided by the Statistics Finland. This was not as such available for the years 1986–1994, as integrated pulp and paper production were aggregated in the Industrial Statistics for those years. Working hours in pulp production were separated from the total working hours in integrated pulp and paper production by extrapolating from past developments in the pulp and paper industry. Wage cost is the total sum of wages and social security costs in the pulp and paper industry divided by the total number of working hours.

The National Accounts provide an updated series for the net stock of capital for the aggregate of pulp, paper and paper products. We separated the capital stock for pulp from the total capital stock for the pulp, paper and paperboard industries, using share weights obtained from the respective (older) series of Industrial Statistics. Again, this method was only applicable up to the year 1985 and for the rest of the observations, the production capacity for pulp and paper was used as a reference for separating the net stock of pulp from the aggregate capital stock. Due to high correlation between the capital stock series for the pulp and paper industry and for the pulp industry exclusively, the choice between the two capital stock values does not make a difference in estimation.

ESTIMATION RESULTS

The model was estimated using Zellner's iterative seemingly unrelated regression method in a stochastic form with additive disturbance terms. We report four alternative estimations (Models A, B, C and Model A with dummy variables). In Model A imperfect competition is allowed in the pulpwood market, while in Model B it is allowed in the market for wood chips. To avoid having the markdown parameter χ ($\chi = 1 + \gamma\theta$) appear under the square root sign, we introduced the parameter for $\sqrt{\chi}$ and used its square as a parameter in our estimations.

In Model A it was assumed that the pulp industry uses all the wood imports and wood chips that are available to it in a given year and that it buys the additional wood from private forests. Hence the variable part of wood input is domestic roundwood, for which the wood from alternative sources is a perfect substitute. Domestic pulpwood price was used as the representative wood price in Model A. Then we estimated the same system using the wood chip price as a representative wood price (Model B). Here we assumed that the pulp industry purchases its pulpwood before it knows the quantity of wood chips available, and then buys the available wood chips from the sawmills.

In Table 1 most of the parameters in both models A and B were significant and the test statistics for the two models did not differ markedly. Many of the cross-price parameters were significant, which suggests that Leontief-technology (i.e linear equations with respect to input prices) is not a good description of the wood pulp industry. In model A a significant estimate, 0.99, is obtained for $\sqrt{\chi}$, and the Wald test supports the restriction $\sqrt{\chi}=1$ with high probability value (p = 0.97). Hence, the result can not reject the competitive pulpwood market if the wood price at the margin has been determined in the domestic pulpwood market. On the other hand, model B suggests that if industry buys wood chips at the margin, it marks down their price. The estimate 1.21 was obtained for $\sqrt{\chi}$, giving χ an approximate value of 1.47[2]. The obtained Wald-test probability value for restriction $\sqrt{\chi} = 1$ was lower (p = 0.19) than for pulpwood.

If the market has been competitive as suggested by model A, then the actual profits of the pulp industry coincide with the behavioural profit function, as shadow prices for variable inputs do not differ from observed prices in a competitive industry. We included shadow profit (equation 11) in the equation system to check the sensitivity of the parameter estimates to the inclusion of the variable profit equation. The estimate for the variable profit was calculated from the price and quantity data, valuing the alternative wood inputs at their prices and estimating the model with χ restricted to one (Model C). The results were very similar to those of the model A, as can be seen from Table 1.

The own- and cross-price elasticities were calculated at the mean of the variables for Models A–C. All the models gave roughly similar elasticities, of which those of Model C are

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2 It is worth recalling that the low quality of wood chip price data may have an effect on this result (Model B).

given in Table 2. All the own-price elasticities were consistent with the theory since they were positive for pulp output and negative for variable inputs. All the elasticities were less than one, i.e. rather small in absolute terms. For example, the estimated own-price elasticity for pulpwood demand was –0.25 and the price elasticity of pulp supply was 0.15. Labour input was found to be a complement for wood input, in contrast to Hetemäki (1990), which found that labour was a substitute for pulpwood. According to semi-elasticity estimates for technical change, it was found to be wood using and labour saving in the Finnish pulp industry, while in Hetemäki (1990) it was found to be roundwood saving and labour using.

The models however suffer from residual autocorrelation, as indicated by the Durbin-Watson statistics. There is also a problem with the unexplained variation in the wood demand equation, which seems to arise mainly from the wide price and quantity fluctuations in the mid-1970s (1975–77). During this period pulp production and wood consumption plummeted at very high price levels for both pulp and pulpwood. Using separate dummies for these years in model A, residual autocorrelation was reduced as indicated by the rise in Durbin-Watson statistics (see Table 1). Most interestingly, the inclusion of dummies increased the markdown term in the model A, where χ received a significant estimate of 1.37.

In our models, potential markdown was assumed to be constant over the examined time horizon, which is a restrictive assumption. Unfortunately, our experiments using the time-varying markdown parameter, consisting of exogenous variables of the pulpwood model system as in Bergman and Brännlund (1995) produced theoretically incorrect values for markdown, i.e. χ was systematically below one.

CONCLUDING REMARKS

In this paper deviations from competitive pricing of wood were tested using a flexible functional form of factor demand system for the aggregate Finnish pulp industry in 1965–94. Our empirical estimates suggest that the Finnish pulpwood market has on average been competitive during the period. There is, however, some indication that wood chips purchased from the sawmilling industry have been priced below the value of their marginal product. Provided that pulpwood and wood chips are substitutes, this result is qualitatively evident *ex ante* since the price of wood chips has been constantly lower than the price of pulpwood. However, due to residual autocorrelation left in the models and to the fact that the results were sensitive to having all data points of the observation period included, one must be cautious with the conclusion regarding the degree of competition in the pulpwood market. One possible reason for residual autocorrelation in models with rather high explanatory power is nonstationarity of individual time series. Augmented Dickey-Fuller unit root tests (Dickey and Fuller 1979) also indicate that at least two endogenous variables of the system, i.e. pulpwood and pulp quantity, may in fact be nonstationary. Unfortunately, cross-equation restrictions make it difficult to accommodate nonstationarity and possible cointegration in a flexible functional form factor demand model. This approach remains, however, as a possible way to extend this research (see also Aiginger et al. 1995).

Although the strong asymmetry of the Finnish pulpwood market suggests imperfect competition, our results in favour of a competitive market or weak oligopsony power are nevertheless plausible. As concluded by Bergman (1993) for the Swedish roundwood markets, the input market counterpart of the so-called Coase conjecture (Coase 1972) offers an explanation for the wood market pricing. If wood buyers cannot commit themselves not to change the price in the future, the sellers of wood can postpone their decisions to sell and wait until the price eventually rises. Thus the stable market equilibrium in fact converges to the level where the actual wood price equals the value of the marginal product of input, i.e. to the competitive market price. This reasoning is even more suitable to the Finnish pulpwood market than to the Swedish one: the forest industry owns 40 % of the forest area in Sweden while the respective share in Finland is only 9 %, making the Finnish forest industry far more dependent on the nonindustrial private wood supply. Also previous studies on the Finnish wood markets have indicated that price expectations play a crucial role in explaining the forest owner's timber selling behaviour. On the other hand, the signs of imperfect competition in the wood chips market can be explained by the lack of countervailing power of independent sawmills as compared to suppliers of pulpwood.

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REFERENCES:

Aiginger, K., P. Brandner & M. Wüger. 1995. Measuring market power for some industrial sectors in Austria. Applied Economics. Vol 27, 369–376.

Appelbaum, E. 1979. Testing price taking behavior. Journal of Econometrics. Vol 9, 283–294.

Appelbaum, E. 1982. The estimation of the degree of oligopoly power. Journal of Econometrics. Vol 12, 287–299.

Atkinson, S. & Kerkvliet, J. 1989. Dual measures of monopoly and monopsony power: An application to regulated electric utilities. Review of Economics and Statistics. Vol 71, 250–257.

Bergman, M. 1993. The market structure and market power. The case of the Swedish Forest Sector. Umeå Economic Studies No. 296. Dissertation.

Bergman, M. & Brännlund, R. 1995. Measuring oligopsony power. An application to the Swedish Pulp and Paper industry. Review of Industrial Organization. Vol 10, 307-321.

Bernstein, J.J. 1992. Price margins and capital adjustment. Canadian mill products and pulp and paper industries. International Journal of Industrial Organization. Vol 10, 491–510.

Bernstein, J.I. & Mohnen, P. 1991. Price-cost margins, exports, and productivity growth: with an application to Canadian industries. Canadian Journal of Economics. Vol 24, 638–659.

Bresnahan, T. 1989. Empirical studies of industries with market power. In: Schmalensee, R. & Willig, R.D. Handbook of industrial organization. Elsevier Science Publishers. Vol II, 1011–1056.

Coase, R. 1972. Durability and Monopoly. Journal of Law and Economics. Vol 15:143–149.

Dickey, D.A. & Fuller, W.A. 1979. Distribution of estimates for autoregressive time series with unit root. Journal of American Statistical Association. Vol 74, 427–431.

Hetemäki, L. 1990. Factor substitution in the Finnish pulp and paper industry. Acta Forestalia Fennica 211. The Society of Forestry in Finland and Finnish Forest Research Institute. 87 p.

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

Just, R. & Chern, W. 1980. Tomatoes, technology and oligopsony. Bell Journal of Economics. Vol 11, 584–602.

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.

Murray, B.C. 1995. Measuring the oligopsony power with shadow prices: U.S. Markets for pulpwood and sawlogs. The Review of Economics and Statistics. Vol 77, 486–498.

Schroeter, J. 1988. Estimating the degree of market power in the beef packing industry. The Review of Economics and Statistics. Vol 70, 158–162.

Schroeter, J. & Azzam, A. 1990. Measuring market power in multi-product oligopolies: the US meat industry. Applied Economics. Vol 22, 1365–1376.

Slade, M. 1995. Empirical games: the oligopoly case. Canadian Journal of Economics. Vol 28, 368–402.

Tirole, J. 1988. The Theory of Industrial Organization. MIT Press, Cambridge. 479 p.

Toppinen, A. & Kuuluvainen, J. 1997. Structural changes in the Finnish sawlog and pulpwood markets. Scandinavian Journal of Forest Research. Vol 12, 382–389.

Wann, J. & Sexton, R. 1992. Imperfect competition in multiproduct food industries with application to pear processing. American Journal of Agricultural Economics. Vol 74, 980–990.

Table 1. Parameter estimates for alternative iterative seemingly unrelated regression models. (*t*-values in parentheses on the right to the coefficients and Durbin-Watson statistics below coefficients of determination). The subscripts are: *q* for pulp, *l* for labor, *w* for wood, *T* for technological change, and *K* for capital.

	Pulpwood price A Imperfect competition χ=free	Residual wood price B Imperfect competition χ=free	Pulpwood price C Perfect competition χ=1	Pulpwood price A + Dummy variables Imperfect competition χ=free
$\sqrt{\chi}$	0.99 (6.53)	1.21 (7.51)	–	1.17 (15.56)
β_{qq}	6.75 (6.40)	5.96 (9.28)	5.90 (10.79)	8.36 (8.39)
β_{ll}	–29.87 (–5.50)	–20.12 (–4.23)	–27.42 (–5.53)	–27.67 (–5.45)
β_{ww}	–9.89 (–1.98)	–12.50 (–3.71)	–4.48 (–1.53)	–0.28 (–0.06)
β_{ql}	–2.36 (–4.48)	–3.29 (–4.95)	–2.43 (–4.64)	2.59 (4.92)
β_{wl}	7.16 (4.75)	9.22 (5.57)	6.71 (4.64)	6.05 (4.35)
β_{qw}	–4.96 (–2.46)	–3.29 (–3.95)	–5.27 (–8.36)	–8.96 (–4.47)
$D75_q$	–	–	–	–1.97 (–6.04)
$D76_q$	–	–	–	–1.71 (–5.47)
$D77_q$	–	–	–	–1.76 (–5.77)
μ_{TT}	–	–	–4.75 (–2.88)	–
μ_{TK}	–	–	0.00 (4.28)	–
ϕ_{qK}	0.00 (0.16)	0.00 (0.12)	0.00 (1.66)	0.00 (2.61)
ϕ_{qT}	0.14 (5.11)	0.15 (5.66)	0.12 (4.75)	0.10 (5.64)
ϕ_{lK}	–0.00 (–7.13)	–0.00 (–7.34)	–0.00 (–7.80)	–0.00 (–7.25)
ϕ_{lT}	1.04 (10.26)	0.90 (10.07)	1.03 (11.05)	1.01 (10.58)
ϕ_{wT}	–0.55 (–4.39)	–0.63 (–5.26)	–0.44 (–3.97)	–0.33 (–4.44)
ϕ_{wK}	–0.00 (–0.22)	–0.00 (–0.36)	–0.00 (–1.85)	–0.00 (–2.66)
$D75_w$	–	–	–	8.28 (6.24)
$D76_w$	–	–	–	7.44 (5.86)
$D77_w$	–	–	–	7.11 (5.72)
Equation: Π				
Adj. R^2	–	–	0.79	–
(DW)			(0.59)	
Equation: Q				
Adj. R^2	0.78	0.78	0.77	0.93
(DW)	(0.58)	(0.63)	(0.53)	(1.09)
Equation: $-X_w$				
Adj. R^2	0.73	0.72	0.71	0.92
(DW)	(0.58)	(0.62)	(0.52)	(1.14)
Equation: $-X_L$				
Adj. R^2	0.97	0.97	0.97	0.97
(DW)	(0.70)	(0.91)	(0.66)	(0.68)

Table 2. Elasticities for model C, calculated at the mean of the variables.

	Pulp price	Wood cost	Labor cost	Capital stock	Technical change
Pulp supply	0.15	–0.12	–0.03	0.20	0.27
Wood demand	0.32	–0.25	–0.07	0.27	0.27
Labor demand	0.29	–0.27	–0.03	0.48	–0.66

IV

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, test 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: stumpage market, regional prices, law of one price, market integration, cointegration, short-run dynamics

1. 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 and 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 and 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 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 and Kuuluvainen 1992, Toppinen and 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

[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 years. 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

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, 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 Finnish 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.

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prices in the Finnish roundwood market, transaction by transaction.

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

2. 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 and 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 and Judge (1971) model of spatial competitive equilibrium in 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, 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 and 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

[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 and Petzel 1984). In this paper we do

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 and Benson 1990).

Traditionally, market integration has been analysed using correlation and single-equation regression analysis (see e.g. Stigler and 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 and 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 and Scroeder (1991) on U.S. cattle markets, Alexander and Wyeth (1994) on Indonesian rice markets, and Bessler and 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 and 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 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 by Jung and 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

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not, however, consider this aspect of market integration strong law of one price holds between spruce sawlog markets. Murray and 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 and Granger (1987).

3. 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 and Fuller 1979). As introduced by Engle and 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 and 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 and 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 and 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 and 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:

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

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

[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.

$\chi 2(r)$.

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 and 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 α_i loading in cointegration analysis is zero (for more details, see Johansen 1995, p.77–78).

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 and Jayasuriya 1994). As the error-correction representation (e.g. Engle and 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.

4. 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 on-line 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 and 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.

5. 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 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 and 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 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 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

[5] E.g. Blank and 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.

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, 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 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 and Kuuluvainen 1997); it was found to increase traded pulpwood quantities in the Finnish roundwood market. However, it has to

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[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.

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 and 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 and 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.

6. 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 and 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 and spruce pulpwood, the cointegration rank test indicated two separate cointegrating vectors and two common trends. For spruce sawlogs 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 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. Modeling of agricultural markets and prices using causality and path analysis. North Central Journal of Agricultural Economics. Vol. 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. Vol. 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. 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. 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.

Gonzalo, J. 1994. Five alternative methods of estimating long-run equilibrium relationships. Journal of Econometrics. Vol. 55: 203–233.

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. 1998. The law of one price in United Kingdom soft sawnwood imports – a cointegration approach. Forest Science. Vol. 44: 17–23.

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. In: Structural change in NIPF ownership and the use of forests in Finland. (eds.

Ovaskainen, V. & Kuuluvainen, J.) 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. Vol. 66: 481–487.

Murray, B. & Wear, D. 1998. Federal timber restrictions and interregional arbitrage in U.S. lumber. Land Economics. Vol 74: 76–91.

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. 1998. Spatial integration in the Nordic timber market: long-run equilibria and short-run dynamics. Forthcoming in Scandinavian Journal of Forest Research. Vol 13.

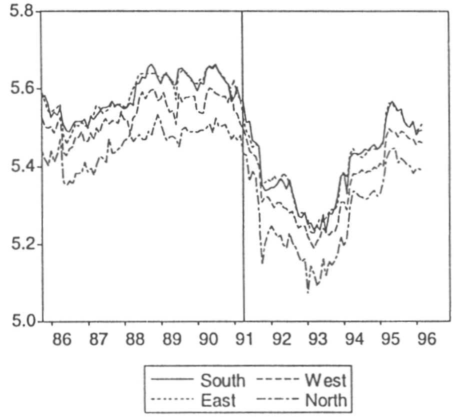
Toppinen, A. & Kuuluvainen, J. 1997. Structural changes in sawlog and pulpwood markets in Finland. Scandinavian Journal of Forest Research. Vol 12: 382–389.

Uri, N. & Boyd, R. 1990. Considerations on modelling the market for softwood lumber in the United States. Forest Science. Vol. 36: 680–692.

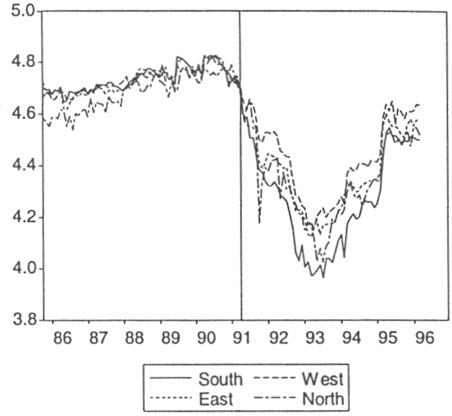
Uusivuori, J. & Mykkänen, R. 1996. European competition policy in the Finnish Forest Sector. Pellervo Economic Research Institute. Reports and discussion papers 138. 72 p.

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)

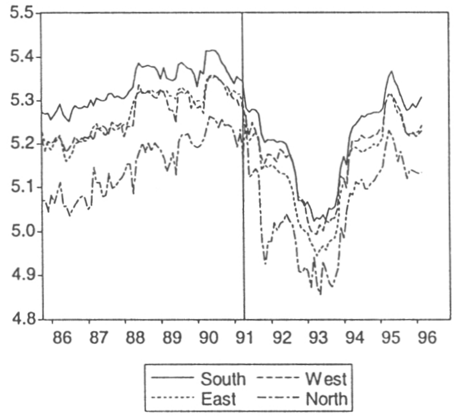
Pine sawlog



Pine pulpwood



Spruce sawlogs



Spruce pulpwood

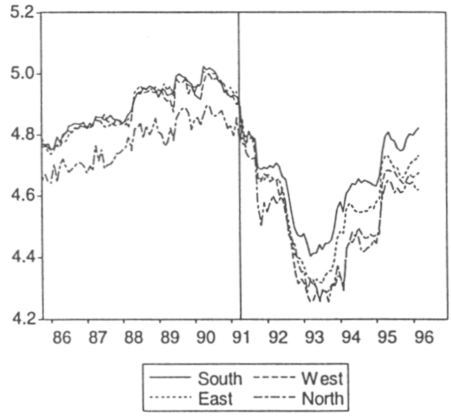


Figure 1. Graphs of the regional stumpage prices (real prices in logs) where vertical line indicates the end of collective stumpage price recommendations in Spring 1991.

Table 1. ADF-test results for roundwood prices by regions in Finland from model specification including a constant, a trend variable and three lags.

Prices	ADF-test by[1] 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*

1) * denotes the rejection of null hypothesis of nonstationarity. The critical value for the ADF test –4.03 at 5 % level (see e.g. Dickey and Fuller 1979).

Table 2. 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 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 and Hendry 1994). For further details and test references, see Doornik and Hendry (1994).

Table 3. Normalized unrestricted eigenvectors and their weights in pine and spruce sawlog and pulpwood systems.

	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

Table 4. 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_0:	$r = 0$	$r \leq 1$	$r \leq 2$	$r \leq 3$	H_0: r=3[2]
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 %[1]	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	

1 Indicates critical values from Johansen and Juselius (1990) and ** indicates significance at 1 % level and * at 5 % level.

2 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.

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**

** (*) indicates rejection of weak exogeneity at 1 % (5 %) level. According to the *r* used, critical $\chi2(2)$ value is 5.99 and $\chi2(3)$=7.82 at 5 % level.

Table 6. 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_0:	$r=0$	$r\leq 1$	$r\leq 2$	$r\leq 3$
Trace test 95 %[1]	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

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
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:	D(Southern price)	D(Western price)	D(Northern price)
Constant	–0.00	0.06	–0.15
	(–0.03)	(2.99)	(–4.81)
D(Southern price(–1))	–0.22	–0.05	–0.12
	(–2.61)	(–0.61)	(–0.88)
D(Western price(–1))	0.14	–0.10	–0.03
	(1.65)	(–1.14)	(–0.24)
D(Northern price(–1))	0.02	0.01	0.05
	(0.28)	(0.12	(0.53)
D(Eastern price)	0.75	0.78	0.75
	(12.04)	(12.43)	(7.45)
ECM1(–1)	–0.29	–0.21	0.21
	(–5.26)	(–3.68)	(2.27)
ECM2(–1)	0.20	–0.16	0.26
	(3.70)	(–3.00)	(3.00)
ECM3(–1)	–0.07	–0.17	–0.35
	(–1.80)	(–4.13)	(–5.25)
S199103	–0.00	–0.00	0.01
	(–0.37)	(–0.84)	(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:	D(Southern price)	D(Eastern price)	D(Western price)
Constant	0.44	0.14	0.58
	(4.20)	(1.20)	(4.84)
D(Southern price(–1))	–0.60	–0.26	–0.17
	(–4.63)	(–1.79)	(–1.14)
D(Eastern price(–1))	0.53	0.34	0.31
	(4.0)	(2.35)	(2.09)
D(Western price(–1))	0.29	0.15	0.01
	(2.72)	(1.23)	(0.11)
D(Northern price)	0.14	0.23	0.23
	(3.49)	(4.99)	(5.05)
ECM1(–1)	0.03	0.02	0.04
	(4.71)	(2.23)	(5.66)
ECM2(–1)	–0.09	–0.39	–0.21
	(–0.83)	(–3.25)	(–1.70)
S199103	0.00	–0.00	0.00
	(0.30)	(–0.41)	(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)	

Continued...

Pine pulpwood:	D(Eastern price)	D(Northern price)
Constant	0.52	0.57
	(5.19)	(2.87)
D(Eastern price(–1))	0.13	–0.06
	(1.47)	(–0.36)
D(Northern price(–1))	–0.01	–0.12
	(–0.37)	(–1.24)
D(Southern price)	0.48	0.37
	(7.09)	(2.79)
D(Western price)	0.23	0.31
	(3.17)	(2.18)
ECM1(–1)	0.07	–0.16
	(3.43)	(–4.03)
ECM2(–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:	D(Western price)	D(Northern price)
Constant	0.02	0.06
	(1.94)	(4.28)
D(Western price(–1))	–0.23	0.13
	(–2.69)	(1.10)
D(Northern price(–1))	0.16	–0.21
	(2.09)	(–1.89)
D(Western price(–2))	–0.17	–0.03
	(–2.15)	(–0.25
D(Northern price(–2))	0.11	–0.02
	(1.78)	(–0.20)
D(Southern price)	0.52	0.34
	(3.79)	(1.77)
D(Eastern price)	0.47	0.31
	(3.81)	(1.76)
ECM1(–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)	

V

Incorporating cointegration relations in a short-run model of the Finnish sawlog market

Anne Toppinen

Abstract: This paper reports on the results of a simultaneous equations sawlog market model using monthly data for Finland in 1985–1997. Johansen's multivariate method is used to estimate cointegration vectors, which are then included in a dynamic error-correction model. Rank tests indicate two cointegrating vectors, which is theoretically consistent with the demand and supply equations. In the sawlog demand, the equilibrium is established for sawlog stumpage price and quantity and sawn wood price and capital stock, while the supply function in a perfect capital market entails sawlog price and quantity, real interest rate, and the effect of increasing timber stock as captured by a linear trend. Contrary to earlier findings, stumpage price seems to have a positive effect on sawlog supply, both in the short and long run, while only the long-run price effect is present in the sawlog demand. Disequilibrium in demand is corrected within one quarter, while the speed of adjustment is found to be slow in the sawlog supply.

Résumé : Cet article présente les résultats d'un modèle à équations simultanées pour le marché des billes de sciage qui utilise des données mensuelles recueillies en Finlande entre 1985 et 1997. La méthode multivariée de Johansen est utilisée pour estimer les vecteurs de cointégration, lesquels sont inclus dans un modèle dynamique de correction des erreurs. Des essais de classification montrent deux vecteurs de cointégration, ce qui est théoriquement compatible avec les équations de l'offre et la demande. Pour la demande en billes de sciage, l'équilibre est établi pour la valeur sur pied, la quantité des billes de sciage, le prix du bois scié et la valeur en capital, alors que l'offre, dans un marché capitaliste parfait, détermine le prix et la quantité de billes de sciage, le taux d'intérêt réel et l'effet d'une augmentation du stock de bois sur pied telle que décelée par une tendance linéaire. Contrairement aux travaux antérieurs, la valeur sur pied semble avoir un effet positif sur l'offre de billes de sciage, à la fois à court et à long terme, tandis que seule l'influence à long terme du prix est présente dans la demande de billes de sciage. Un déséquilibre dans la demande est corrigé à l'intérieur d'un trimestre alors que la vitesse d'ajustement est plutôt lente pour l'offre de billes de sciage.

[Traduit par la Rédaction]

Introduction

The contribution of this paper is that we extend the previous empirical work on short-run price and quantity determination for the roundwood markets (e.g., Brännlund et al. 1985; Newman 1987 and Kuuluvainen et al. 1988) by using recent developments in time series econometrics. This issue is of special interest because violation of stationarity of individual time series, implicitly assumed in many previous roundwood market models, may reduce the validity of the statistical inferences from the results. In particular, we study long-run equilibrium relationships, i.e., cointegration (Engle and Granger 1987; Banerjee et al. 1993) between the key factors in the market, and incorporate this information in a short-run market model. If time series are nonstationary and cointegrated, the information on equilibrium relationships provides essential information on price and quantity determinants in the market. Moreover, weak short-run forecasting performance has also been one of the problems in many previous models for roundwood markets. Using this new methodology we hope to be able to specify better short-term models for forecasting wood prices and quantities, enhancing efficiency in the strongly cyclical wood markets.

Our empirical work employs multivariate cointegration techniques, as developed by Johansen (1988, 1995). During the 1990s, Johansen's multivariate cointegration estimation procedure (Johansen 1988; Johansen and Juselius 1990) has become the most frequently applied method for estimating long-run equilibrium relationships in econometric models. Applications that identify the simultaneous equations structure in cointegration space and incorporate it in a dynamic short-run model are still rare (see, however, Johansen and Juselius 1994; Kongsted 1995) and to my knowledge are nonexistent in the forest economics literature.[1]

The paper is organized as follows. Institutional environment in the Finnish roundwood market is briefly described in the second section. The theoretical model for the demand and supply of stumpage, based on previous work in the area, is discussed in the third section. The fourth section describes the empirical data and background for the multivariate cointegration analysis. In the fifth section we obtain maximum likelihood estimates of the price and quantity determinants for the sawlog market both in the short and long run, and the sixth section contains summary and conclusions.

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[1] Ripatti (1990) established a long-run structure for sawlog and pulpwood markets in Finland using Johansen's estimation procedure and annual data for 1960–1985, but did not estimate the short-run dynamics of the model. Moreover, the data and the economic model used in the present study are presumably more suitable for forecasting in the market environment of the 1990s in Finland.

Institutional environment in the Finnish roundwood market

Forest sector is an important part of the Finnish economy, bringing roughly 40% of the net export earnings to the country. Because 75% of sawn wood production and 90% of paper production is being exported, mainly to European Union, cyclical fluctuations in export markets are carried to domestic wood markets. The situation is similar to, for example, Swedish wood market and affected by the business fluctuations in the U.S. through the Canadian exports of lumber to Europe.

In Finland 300 000 nonindustrial private forest (NIPF) owners supply 70–80% of domestic wood raw material, and the residual consists of state forests and forests owned by the forest industry. Unlike in most European countries, stumpage sales account for over two-thirds of purchased roundwood in Finland. In the following, we will concentrate on modelling the private share of Finnish roundwood trade using data on stumpage prices.

Following, for example, Brännlund et al. (1985) and Newman (1987), we assume in this study that there are separate markets for sawlogs and pulpwood. Both wood assortments account for approximately one-half of the sales volume. However, because of relatively high stumpage prices for sawlogs, they represent over 60% of stumpage earnings to NIPF owners.

The number of buyers is high in the Finnish sawlog market, altogether 170 sawmills produced 9.2×10^6 m^3 sawn wood in 1996, while in the pulp industry the three major companies presently purchase over 90% of pulpwood.[2] In Finland, the competitive equilibrium market assumption is therefore more likely to be met in the sawlog market than in the highly concentrated pulpwood market. Subsequently, the empirical analysis in this paper concerns only the sawlog part of the Finnish roundwood market.

Theoretical framework

The representative forest industry enterprise in the sawmill industry is assumed to sell its outputs (Y_i) in competitive markets at a given price. The output of the forest industry firm can be described using a continuous, strictly concave, and twice differentiable production function, $Y = f(K, Q)$, where K is capital input and Q is material (roundwood) input. In the short run, capital is assumed to be fixed, and therefore net capital stock enters the model instead of capital user cost. The other inputs, most importantly labour and energy, were excluded from the model because of a lack of data. However, the cost share of capital costs and wood costs at the sawmill alone is very high: in 1991 they accounted for 73% of total costs in the Finnish sawmilling industry. The profit-maximizing problem of a representative sawmill leads to the implicit sawlog demand equation:

$$[1] \quad D_t = f(\underset{-}{\text{psl}_t}, \underset{+}{\text{psw}_t}, \underset{+}{c_t})$$

where psl is sawlog price, psw is export price of sawn wood, and c is capital stock. The comparative static effects below the coefficients indicate that a rise in the sawn wood world market price and the capital stock of the sawmilling industry both increase the demand for sawlogs, while the rise in stumpage price decreases demand (e.g., Johansson and Löfgren 1985).

The behavioural timber supply function is based on a dynamic Fisherian consumption-savings model of a utilility-maximizing representative NIPF owner in perfect capital markets. Therefore, the income from the optimal present value maximizing harvest can be allocated for optimal intertemporal consumption via the capital market (see Kuuluvainen 1990). Consequently, the supply of sawlogs in period t depends positively on the current stumpage price, the interest rate, and the initial timber stock and negatively on the expected stumpage price:

$$[2] \quad S_t = f(\underset{\pm}{\text{psl}_{t,\,t+1}}, \underset{+}{\text{ir}_t}, \underset{+}{v_t})$$

where psl is sawlog price in time periods t and $t + 1$, ir is the short-term market interest rate, and v is the initial timber stock in the first period. The use of short-term interest rate is justified in modelling timber supply from given stock, while the expected average long-term interest rate would be more suitable in modelling, for example, the optimal forest rotation period. For formal derivation of this equation and a detailed discussion of the comparative static effects under perfect and imperfect capital markets, the reader is referred, for example, to Kuuluvainen (1990) or Koskela (1989).

Harvesting costs are not included in the theoretical model because in Finland they represent a relatively constant fraction of the mill price of wood over a business cycle and thus do not affect the short-run supply or demand for wood. In addition, logging and transportation of wood is mainly carried out by the buyers of sawlogs and pulpwood directly. It would be possible to include also the pulpwood price in the sawlog supply equation, as, for example, in Brännlund (1988), but this cross-price effect was omitted because of a high positive correlation (0.94) between the two stumpage prices.

Data and methods

Time series data

For the wood price and quantity variables, we used total quantity of coniferous sawlogs (qsl) purchased from nonindustrial private forests. Volume-weighted average stumpage price for pine and spruce sawlogs was used to represent sawlog market price (psl). Stumpage price and quantity variables were collected from statistics published by the Finnish Forest Research Institute.

As the sawn wood price variable, we used the world market price of coniferous sawnwood (psw) as measured by the HWWA index in the Research Institute of Finnish Economy database.[3] As a money market interest rate (ir), the real (i.e., inflation subtracted from nominal interest rate) 3-month interest rate from the *Bank of Finland Year Book* (various years) was used. The choice of this variable is justified because household loans in Finland are mainly based on these short-term

[2] Despite the existence of comprehensive price recommendations in Finland between 1978 and 1991, earlier studies (e.g., Kuuluvainen et al. 1988; Toppinen and Kuuluvainen 1997) have indicated that the competitive market structure could be an adequate market description for Finland.

[3] In preliminary analyses sawn-wood unit export price (freight on board) from Customs statistics was also used, and the results were qualitatively similar. Our choice of the HWWA index was based on the availability of more recent observations.

Table 1. Results from the unit-root tests for individual variables.

Variable[a]	ADF-test level[b]	ADF-test 1st diff.[b]
psl	−0.8 (2)	−7.2 (1)**
qsl	−4.6 (0)**	−9.6 (1)**
psw	−3.0 (2)	−5.7 (0)**
c	−1.6 (2)	−9.8 (2)**
ir	−2.0 (1)	−10.6 (0)**

Note: The number of lagged differences in the test equation is given in parentheses. *, **, rejection of the null hypothesis of nonstationarity at the 5% and 1% levels, respectively.

[a]psl, sawlog price; qsl, sawlog quantity; psw, sawn wood price; c, capital stock; ir, real interest rate.

[b]Critical values are −3.45 at the 5% level and −4.04 at the 1% level.

Table 2. Trace test results for cointegration rank in the sawlog model.

H_0: $r \le i$	Eigenvalue λ	Trace statistic	Trace statistic $T - nm$[a]	95% critical value
r=0	0.30	120.4**	106.9**	87.3
r≤1	0.21	72.5**	64.4*	63.0
r≤2	0.12	40.5	35.9	42.4
r≤3	0.12	22.9	20.3	25.3
r≤4	0.04	6.0	5.3	12.2

Note: *, **, test statistic significant at the 5% and 1% levels, respectively.

[a]$T - nm$ test specification is with the degrees of freedom correction in data.

interest rates, and it therefore reflects well the opportunity cost of selling wood.

As data on net capital stock for the sawmill industry were not available at a monthly frequency, we used the volume of industrial production in the sector as a proxy for production capacity (c). This is an approximate measure of the capacity as in Brännlund and Löfgren (1995), but without doing any deterministic correction to potential output measure by joining successive production peaks by straight lines.[4] Because no monthly data were available on timber stock either, we let the deterministic trend (t) represent a constantly increasing timber stock during the study period. It can be argued that deterministic trend describes relatively well the slowly evolving data on timber stock (see also Doornik and Hendry 1994, p. 75).

All prices of this study were deflated using the consumer price index. The model was estimated for the period October 1985 through February 1997, giving us 137 observations. The number of observations is well within the range required in order for the asymptotic properties of multivariate cointegration analysis to hold (e.g., Johansen and Juselius (1990, 1994) used samples of 57 and 63 quarterly observations, respectively). The choice of estimation period was partly dictated by the lack of monthly data on wood prices and quantities prior to 1985. Moreover, deregulation of the capital markets in the mid-1980s substantially changed the economic environment of NIPF owners in Finland. Therefore, the earlier data would not necessarily contain relevant information for modelling and forecasting the timber market in the late 1980s and 1990s (see also Pajuoja 1995; Toppinen and Kuuluvainen 1997).

Methods of analysis

In the applied economic time series analysis, testing for the existence of unit roots in the data and cointegration between variables have become standard procedures in the 1990s. According to Banerjee et al. (1993), for example, a time series is denoted $I(0)$ when it is stationary already in levels and $I(d)$ when it must be differenced d times in order to achieve (weak covariance) stationarity. Further, it has become customary to use either augmented Dickey–Fuller (ADF) or Phillips–Perron unit-root tests in testing for nonstationarity (Dickey and Fuller 1979; Phillips and Perron 1988). As introduced by Engle and Granger (1987), cointegration is a statistical property of data that can describe the long-run co-movement of 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. Following Johansen (1995), the unrestricted p-dimensional vector autoregressive (VAR) model can be formulated as

$$[3] \quad \Delta x_t = \Gamma_1 \Delta x_{t-1} + \ldots + \Gamma_{k-1}\Delta x_{t-k+1} + \Pi x_{t-1} + \mu + \Phi D_t + \varepsilon_t \qquad t = 1, \ldots, T$$

where p is the number of variables in the system. The constant term (μ) can be restricted to cointegrating space to represent the absence of linear trend in the data. Seasonal dummies (D) can be included in the analysis if quarterly or monthly data are used. Introducing sufficient lags (k) usually produces a well-behaved error term of NID(0, Ω). Assuming that $x_t \sim I(1)$, i.e., integrated of order one, the components of x_t are cointegrated when the rank, r, of the impact matrix Π is greater than zero but less than p. If r equals zero, the variables are not cointegrated. If the rank is full, i.e., r equals p, the variables are stationary by themselves and the normal statistical inference applies.

The rank of the long-run matrix, $\Pi = \alpha\beta'$, determines the number of cointegrating vectors, i.e., the equilibrium relationships between the variables. 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.[5]

A likelihood ratio test devised by Johansen (1988) is used to measure the number of cointegrated vectors in the data. This so-called trace test for testing the rank of the cointegrating matrix is calculated as

$$[4] \quad \text{Trace}(r) = -T \sum_{i=r+1}^{p} (1 - \hat{\lambda}_i)$$

where T is the number of observations and $\hat{\lambda}_i$ refers to the estimated eigenvalues. The null hypothesis (H_0) is rank (Π) $\le r$,

[4] There is not necessarily an endogeneity problem between sawlog quantity and production volume, because timber purchased now enters production on the average 5 to 6 months later. Nevertheless, we will empirically test for endogeneity of sawn wood production in cointegration analysis.

[5] For a comprehensive discussion on multivariate cointegration analysis, the reader is referred to Johansen (1995) or Banerjee et al. (1993).

Table 3. Cointegrating vectors (β_i) and their loadings (α_i) from the unrestricted cointegration model.

	β_1	β_2	β_3	β_4	β_5	α_1	α_2	α_3	α_4	α_5
qsl	**1.00**	0.10	0.05	0.35	0.09	−0.36	−1.01	−0.34	−0.27	−0.00
psl	−2.47	**1.00**	−0.39	−2.96	1.22	0.00	−0.08	−0.01	−0.04	0.00
psw	0.54	−0.37	**1.00**	−0.98	−1.33	−0.00	−0.03	−0.06	0.03	−0.00
c	0.17	−1.00	0.43	**1.00**	1.99	0.03	0.13	−0.15	−0.03	−0.03
ir	−1.04	0.10	0.09	1.49	**1.00**	0.03	0.05	0.02	−0.08	0.00
t	−0.01	0.00	0.00	0.01	0.00					

and the alternative (H_1) hypothesis is that the number of cointegrating vectors is larger than *r*. In the other test specification, which is called maximum eigenvalue test (λ_{max}), the H_0 is rank $(\Pi) = r - 1$ against the alternative that the rank equals *r*.

The main advantage of the Johansen procedure is in the testing and estimation of the multiple cointegration vectors. It is also possible to test various economic hypotheses via linear restrictions in the cointegration framework (cf. Johansen and Juselius 1990). For example, the hypothesis of weak exogeneity of variables can be formulated under a certain rank, *r*, of the cointegrating space by using restrictions on the α matrix. If the hypothesis $B'\alpha = 0$ (i.e., that the respective row of loadings, α, is restricted to zero) can be accepted, then a variable Δx_t is weakly exogenous to the long-run parameters α and β. Because linear restrictions are conditional on the cointegration rank, they are in $I(0)$ space and conventional χ^2 distribution for likelihood ratio tests can be used.

Johansen and Juselius (1994) have further pointed out the identification problem in cointegration structures, which is essentially involved in all simultaneous equations modelling. They distinguish particularly between three different forms of identification, i.e., generic identification, which is related to the rank condition of the linear statistical model, empirical identification, which is related to the estimated parameter values, and economic identification, which is related to the economic interpretability of estimated coefficients of an empirically identified structure.

It seems plausible that the long-run structure of the market model should contain some evidence of at least two behavioural relations. To achieve identification in a demand–supply equation system, it is thus necessary to build the system by including at least one variable that is strongly correlated with demand and uncorrelated with supply, and vice versa (Johansen and Juselius 1994, p. 20).

Briefly, the analysis runs as follows. We first test for nonstationarity of the data set using traditional ADF unit-root tests. The rank of the cointegration space is then estimated by the Johansen multivariate cointegration analysis, modelling all variables first as a system. Weak exogeneity of the variables is then explicitly tested in the estimated cointegration space. Further, the estimated long-run structure is incorporated in the dynamic short-run simultaneous equations model via the use of error-correction parameters (e.g., Davidson et al. 1978). Applying the "general to specific"[6] modelling approach (e.g., Hendry et al. 1988; Spanos 1990), the theoretical zero restrictions (i.e., overidentifying restrictions) from eqs. 1 and 2 are imposed on the short-run model. Finally, the validity of the structural econometric model is judged by applying various misspecification tests and testing the forecasting performance of the model.

Results

Testing for unit roots and cointegration

In testing for nonstationarity of time series, we experimented with various different specifications in ADF test equations (i.e., inclusion of constant, trend, and seasonals and the number of lags from 1 to 13 in the test equation), and the *F*-test procedure in PcFiml was used in choosing the correct test equation reported in Table 1 (see Doornik and Hendry 1994). Results for the ADF tests indicated that for all variables except sawlog quantity, the null hypothesis of nonstationarity was not rejected irrespective of the test equation used. According to the ADF test, the wood quantity series could be an $I(0)$ variable, i.e., stationary without differencing. However, it should be noted that possible stationarity of some variables does not prevent us from estimating rank of cointegration space (see Johansen 1995).

Consequently, cointegration tests were performed for the VAR system, including five variables (i.e., $p = 5$): sawlog price and quantity, sawn wood price, capital stock and interest rate, and a trend representing timber stock. Seasonal dummies were included in the model because the wood quantity variable quite clearly exhibited seasonal variation, while prices in general were not seasonal. A three-lag VAR model was found to be a sufficient statistical representation of the data generation process to remove residual autocorrelation. It was also justified by likelihood ratio tests with sequential decreases in number of lags in the system (see Doornik and Hendry 1994).

Correlation between actual and fitted data was above 0.85 for all individual equations, so the system represented well the variation in the endogenous variables. Correlation between unrestricted reduced form residuals of the sawlog price and quantity equations was 0.44. Some simultaneity thus appears to be present in the Finnish sawlog market.

Both the trace test and the maximum eigenvalue test (not reported) for cointegration rank in Table 2 indicated two cointegrating vectors.[7] The respective eigenvalues, unrestricted

[6] Following Hendry et al. (1988) and Spanos (1990), a distinction between statistical model (reduced form) and econometric model of the system (structural model) is drawn. The system is first specified and tested to be a congruent statistical representation, summarizing sample information. After this, the structural (parsimonious) interpretation to model is derived through imposing zero restrictions implied by economic theory. Validity of structural model is judged on the basis of tests on overidentification restrictions and various other diagnostic tests.

[7] PcFiml 8.0 (Doornik and Hendry 1994) was used in estimating the cointegrating vectors. Testing for general restrictions involving identification of the economic structure was possible using the switching algorithm available in the program.

Table 4. Results for the weak exogeneity tests, restricted standardized cointegration vectors (β_i), and respective weights (α_i) under $r = 2$.

	Weak exogeneity[a] H_0: $\alpha_i = 0$	$\beta_{1\,(DEMAND)}$, $\beta_{51}=\beta_{61}=0$	$\beta_{2(SUPPLY)}$, $\beta_{32}=\beta_{42}=0$	α_1	α_2	LR test statistic[b]
qsl	19.31**	1.00	−0.64	−0.31	0.28	1.11
	[0.0001]	—	(0.06)			[0.57]
psl	13.42**	1.53	1.00	−0.09	−0.04	
	[0.001]	(0.50)	—			
psw	0.63	−1.15	0	−0.00	−0.001	
	[0.73]	(0.37)	—			
c	4.04	−2.18	0	0.03	0.02	
	[0.13]	(0.48)	—			
ir	2.17	0	0.41	0.002	−0.04	
	[0.34]	—	(0.10)			
t		0	0.005			
			(0.001)			

Note: Standard errors are in parentheses and probability values are in square brackets below the coefficients. *, **, rejection of the null hypothesis of weak exogeneity at the 5% and 1% levels, respectively.

[a]The critical χ^2 value is 5.99 at the 5% level.

[b]LR, long run. H_0: $\beta_{51} = \beta_{61} = \beta_{32} = \beta_{42} = 0$ and the critical χ^2 value is 5.99 at the 5% level.

cointegrating vectors (β_i), and their respective loadings (α_i) are presented in Table 3. The role of different variables in the system was examined next by using the weak exogeneity tests under the estimated rank, $r = 2$. The test results presented in Table 4 clearly rejected the weak exogeneity hypothesis for the wood quantity and stumpage price series, while it seems safe to assume that sawn-wood price, capital stock, and interest rate are all weakly exogenous. Concerning the use of production volume as a proxy for capital stock, this result indicates that there is no endogeneity between production and sawlog quantity in our model.

Identification of long-run demand–supply relations

Theoretically justified restrictions from eqs. 1 and 2 were applied to the two cointegrating vectors in order to identify the economic structure of the model. The cointegrating vector β_1 was chosen to be identified as a sawlog demand function by imposing zero restrictions on the coefficients of interest rate and trend (representing timber stock). The second cointegrating vector (β_2) was consequently identified as the supply relationship by imposing zero restrictions on sawn-wood price and capital stock.[8] The chosen identification procedure implicitly normalized the equilibrium demand relation for quantity and the supply relation for stumpage price. In the vector of variables x_t = [qsl psl psw c ir t] we thus assumed the following restrictions:

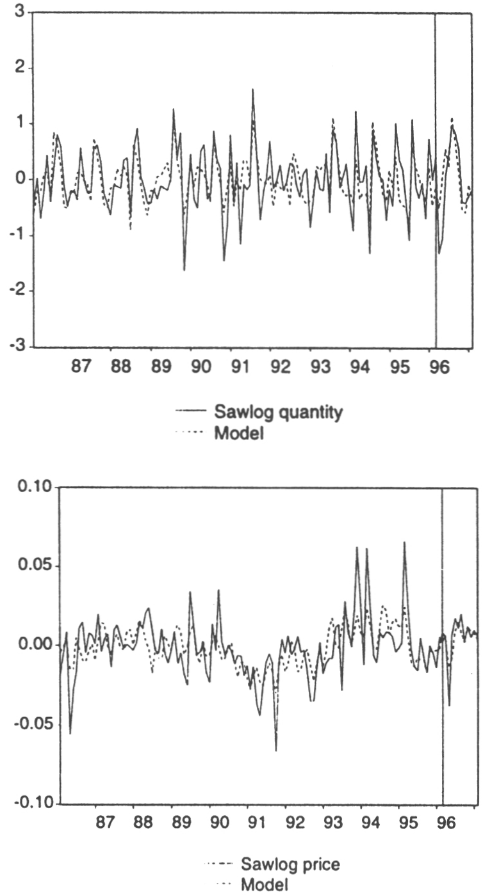
[5] $\beta_1' = [1 * * * 0\ 0]$

[6] $\beta_2' = [* 1\ 0\ 0 * *]$

where * represents a parameter to be estimated freely.

[8] The demand-determined quantity and supply-determined price structure in the Finnish roundwood market has also been applied in Koskela and Ollikainen (1996) using a game theoretic bargaining approach.

Fig. 1. Short-run demand–supply model of the Finnish sawlog market and one-step out-of-sample forecasts for March 1996 – February 1997. The demand equation is a differenced sawlog quantity equation, and the supply equation is a differenced stumpage price equation.



The restricted β-coefficients for the system are presented in Table 4. Most importantly, the identification restrictions on the cointegrating vectors were not rejected by the likelihood ratio test with 2 df. The restricted cointegrating vectors in Table 4 could therefore be interpreted as the relationships representing the equilibrium demand (β_1) and inverse supply (β_2) functions for sawlogs:[9]

[7] $qsl_D = -1.53psl + 1.15psw + 2.18c$

[9] Cointegration vectors were transformed into behavioural equations by shifting the normalized variable to the left handside and reversing the signs of the variables in the cointegrating vector.

Table 5. Maximum likelihood estimates for the dynamic sawlog demand–supply model.

	Sawlog demand (normalized to quantity)[a]		Sawlog supply (normalized to price)[b]
Constant	–0.51 (0.15)**		0.10 (0.02)**
Sawlog price	2.02 (3.84)		0.06 (0.01)**
Sawn wood price	1.25 (0.70)		—
Capital stock	0.68 (0.23)**		-
Real interest rate	—		–0.01 (0.01)
$ECM1_{t-1}$	–0.40 (0.007)**		-
$ECM2_{t-1}$	—		–0.04 (0.008)**
Residual standard error σ	0.40		0.02
Vector autocorrelation Portmanteau 12 lags[b]		69.33	
Vector heteroscedasticity (30, 273)		1.23 (0.19)	
Vector normality χ^2 (4)		3.12 (0.54)	
System overidentification χ^2 (3)		3.18 (0.36)	
Forecast test F (24, 106)		0.96 (0.52)	

Note: Standard errors for parameters are in parentheses. *, **, test statistic is significant at the 5% and 1% levels, respectively.
[a]All variables are in first differences except the lagged error-correction terms. The estimates and standard errors for 11 seasonal dummies are omitted for brevity.
[b]For more information on different diagnostic tests, see Doornik and Hendry (1994).

$$[8] \quad psl_S = 0.64qsl + 0.41ir + 0.005t$$

All the coefficients had correct signs, and standard errors of the restricted coefficients were low. Since we used logarithmic variables, the estimated coefficients could be compared with elasticities from the previous studies.

Because of the identification procedure used, eq. 7 could be directly interpreted as the demand equation for sawlogs, with own price elasticity of –1.5. Elasticity of the sawn wood export price was above one (1.2), while the elasticity of capital stock was relatively high, 2.2. Normalizing the eq. 8 also on sawlog quantity yielded a price elasticity of sawlog supply of 1.6, while the elasticity of interest rate was 0.6 and that of trend representing timber stock was 0.01. The positive coefficient of the interest rate in the supply equation was thus consistent with the perfect capital market hypothesis for the Finnish roundwood market in eq. 2 (see also Pajuoja 1995).

The dynamic short-run model

Finally, we focused on two issues: (1) dynamic adjustment of sawlog price and quantity and (2) the impact of changes in exogenous variables. Deviations from the long-run equilibrium, i.e., the restricted cointegrating vectors estimated in the preceding section, were saved and their lagged values were used as error-correction terms. Following the identification procedure in eqs. 5 and 6, lagged β_1 (ECM1) was included in the quantity equation and lagged β_2 (ECM2) was included in the price equation.

A partial two-lag model from eq. 3 for sawlog price and quantity was then estimated using variables in first differences. According to F-tests, the lags of differenced variables did not significantly contribute to explaining variation in endogenous variables, and they were dropped from the estimation results reported in Table 5.[10] Twelve observations at the end of the study period were excluded from the estimations and used for the out-of-sample forecasting test.

Estimation results for the simultaneous equations model indicated that our simple dynamic model was able to capture the essential features of the sawlog market well. According to the various diagnostic tests, there were no diagnostic problems with the model. Most importantly, the overidentification test for the model structure was not rejected. One-step-ahead forecasting properties of the model were found to be acceptable in the out-of-sample testing for the period from March 1996 to February 1997 (Fig. 1).

As compared with theoretical model in the third section and estimates from the cointegration relationships, some differences emerged. However, it has to be borne in mind that the economic theory in general is about long-run relationships, and this theory does not actually provide hypotheses for the signs or magnitudes of the coefficients in the empirical short-run models nor does it give hypotheses concerning the explicit adjustment process to equilibrium. The positive impact effect of stumpage price on sawlog demand was not significantly different from zero in the dynamic model. The impact effect of stumpage price on supply was statistically significant at the 1% level, but it was difficult to give economic interpretation to the absolute size of the coefficient.[11] The impact effect of sawn wood price on sawlog demand was slightly above one in absolute value, but significant only at the 8% level. The positive effect of capital stock on sawlog demand was significant and approximately one-third the size of the long-run effect. Finally, the impact effect of the interest rate on sawlog supply was not different from zero in comparison to the significantly positive long-run effect in eq. 8.

Further, the estimated error-correction terms entered both the demand and supply equations with highly significant t-values.

[10] Also 11 seasonal dummies were included in the short-run model to capture deterministic seasonality. They are excluded from Table 5 for brevity, since their coefficients do not have economic interpretation as such and only 3 of 11 were statistically significant.

[11] The higher stumpage price effect in the short-run model than in the cointegration model is likely to be related to some exceptional observations during research period, where small changes in the recommended stumpage prices caused relatively large short-run quantity changes.

Hence, results regarding the identification of long-run structure in the previous section were reinforced by the short-run model. The estimated error-correction term in the demand equation implied rapid correction of disequilibria, i.e., within one-quarter of a year. In the supply equation, normalized to stumpage price, the adjustment coefficient was found to be very small, indicating slow adjustment. Except that confirming the general view in the market that demand factors are most important in the adjustment to equilibrium sawlog quantity in Finland, this result may be also partly derived from using monthly data. Considering publication lags in stumpage price statistics and the infrequency of sawlog sales from an average private forest owner, a month is a very short time from the NIPFs' point of view, while buyers of sawlog are acting on the market throughout the year.

Summary and conclusions

In this paper we reformulated the short-run demand and supply models of the Finnish sawlog market by employing recent developments in time series econometrics, i.e., Johansen's multivariate cointegration analysis and the "general to specific" modelling approach as proposed by Hendry and Spanos.

Our main result using Johansen's cointegration analysis was that the equilibrium assumption seems to be well suited to the Finnish sawlog market.[12] More specifically, there was evidence of two cointegration vectors, which we could identify as the supply and demand for sawlogs. Based on the weak exogeneity tests and the results from the short-run model, disequilibrium in the Finnish sawlog market is corrected through the adjustment of both sawlog quantities and stumpage prices, giving further support to our simultaneous equations error-correction modelling approach.

In general, the results from cointegration analysis coincided with our a priori expectations, since all the coefficients had correct signs and significant t-values. For example, in the sawlog demand the estimated own-price elasticity, −1.5, was slightly higher than in previous models of Finnish markets, i.e., −0.9 in Kuuluvainen (1986) and −1.3 in Kuuluvainen et al. (1988). On the other hand, the sawn wood price elasticity of 1.2 in this study was lower than that in previous studies, which, of course, used different estimation techniques and data frequency and covered different sample periods. The estimated supply elasticity of sawlogs was 1.6, and above the estimates in some previous studies' hypotheses (e.g., Hetemäki and Kuuluvainen 1992; Toppinen and Kuuluvainen 1997). These studies, however, were based on the imperfect capital market hypothesis, while it is more justified to assume perfect capital markets in Finland when using aggregate market level data of the 1980s and 1990s.

Contrary to earlier findings, stumpage price seems to have a positive effect on sawlog supply in Finland both in the short and long run, while only the long-run price effect is present in the sawlog demand. The effects of sawn-wood price on sawlog price and quantity determination were found to be roughly uniform in the short and long run, indicating that fluctuations from the sawn-wood export markets are efficiently carried into the Finnish sawlog market.

To conclude, our empirical results elaborated the advantages of using the cointegration approach in modelling price and quantity determination in the roundwood market, and a similar modelling approach could benefit studies of these markets in other countries as well.

[12] It should be noted that although our sample size in the multivariate cointegration analysis was sufficient for the asymptotic properties to hold, the available study period, less than 12 years, was relatively short for this type of analysis. However, the results of the cointegration tests were reinforced by the estimation results from the dynamic model, which also implies that we can relatively safely adhere to the estimated model structure.

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References

Banerjee, A., Dolado, J., Galbraith, J., and Hendry, D. 1993. Co-integration, error-correction, and the econometric analysis of non-stationary data. Oxford University Press, Oxford.

Brännlund, R. 1988. The Swedish roundwood market. An econometric analysis. Dissertation. Sveriges lantbruksuniversitet, Umeå. Institution för Skogsekonomi. Rapport 82.

Brännlund, R., and Löfgren, K.G. 1995. Cyclical dumping and correlated business cycles in imperfect markets: empirical applications to the Canadian pulp and paper industry. Appl. Econ. **27**: 1081–1091.

Brännlund, R., Johansson, P-O., and Löfgren, K.-G. 1985. An econometric analysis of aggregate sawtimber and pulpwood supply in Sweden. For. Sci. **31**: 595–606.

Davidson, J.E.H., Hendry, D.F., Srba, F., and Yeo, S. 1978. Econometric modelling of the aggregate time-series relationship between consumers' expenditure and income in the United Kingdom. Econ. J. **88**: 661–692.

Dickey, D.A., and Fuller, W.A. 1979. Distribution of estimates for autoregressive time series with unit root. J. Am. Stat. Assoc. **74**: 427–431.

Doornik, J., and Hendry, D. 1994. PcFiml 8.0. Interactive econometric modelling of dynamic systems. Institute of Economics and Statistics University of Oxford. International Thomson Publishing, London.

Engle, R., and Granger, C.W.J. 1987. Co-integration and error correction: representation, estimation and testing. Econometrica, **55**: 251–276.

Hendry, D., Neale, A., and Srba, F. 1988. Econometric analysis of small linear systems using PC-FIML. J. Econ. **38**: 203–226.

Hetemäki, L., and Kuuluvainen, J. 1992. Incorporating data and theory in roundwood supply and demand estimation. Am. J. Agric. Econ. **74**: 1010–1018.

Johansen, S. 1988. Statistical analysis of cointegrating vectors. J. Econ. Dynam. Control, **12**: 231–254.

Johansen, S. 1995. Likelihood based inference in cointegrated vector autoregressive models. Oxford University Press, Oxford.

Johansen, S., and Juselius, K. 1990. Maximum likelihood estimation and inference on cointegration—with applications to the demand for money. Oxf. Bull. Econ. Stat. **52**: 169–210.

Johansen, S., and Juselius, K. 1994. Identification of the long-run and short-run structure: an application to the ISLM model. J. Econ. **63**: 7–36.

Johansson, P.O., and Löfgren, K.G. 1985. The economics of forestry and natural resources. Basil Blackwell Ltd., London.

Kongsted, H. 1995. Modeling price and quantity relations for Danish manufacturing exports. Paper of the Institute of Economics, University of Copenhagen, Copenhagen.

Koskela, E. 1989. Forest taxation and timber supply under price uncertainty: credit rationing in capital markets. For. Sci. **35**: 160–172.

Koskela, E., and Ollikainen, M. 1996. A game-theoretic model of timber prices with capital stock: an empirical application to the Finnish forest sector. Government Institute of Economic Research in Finland. Res. Pap. 132.

Kuuluvainen, J. 1986. An econometric analysis of the sawlog market in Finland. J. World For. Resour. Manag. **2**: 1–19.

Kuuluvainen, J. 1990. Virtual price approach to short-term timber supply under credit rationing. J. Environmental Econ. Manag. **19**: 109–126.

Kuuluvainen, J., Hetemäki, L., Ollonqvist, P., Ovaskainen, V., Pajuoja, H., Salo, J., Seppälä, H., and Tervo, M. 1988. The Finnish roundwood market: an econometric analysis. Finn. Econ. Pap. **1**: 191–201.

Newman, D. 1987. An econometric analysis of the southern softwood stumpage market: 1950–80. For. Sci. **33**: 932–945.

Pajuoja, H. 1995. Consumption and harvesting decisions on bookkeeping farms in Finland. Doctoral thesis, Publications of the Department of Forest Economics 3, University of Helsinki, Helsinki. [In Finnish.]

Phillips, P.C.B., and Perron, P. 1988. Testing for unit root in time series regression. Biometrika, **75**: 335–346.

Ripatti, A. 1990. Demand and supply of roundwood in Finland, empirical study of the long-run relationships. M.Sc. thesis, Department of Economics, University of Helsinki, Helsinki. [In Finnish].

Spanos, A. 1990. The simultaneous equations model revisited. J. Econ. **44**: 87–105.

Toppinen, A., and Kuuluvainen, J. 1997. Structural changes in sawlog and pulpwood markets in Finland. Scand. J. For. Res. **12**: 382–389.

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