METSÄNTUTKIMUSLAITOKSEN TIEDONANTOJA 662, 1997
THE FINNISH FOREST RESEARCH INSTITUTE, RESEARCH PAPERS 662, 1997

Testing for oligopsony power in the Finnish pulpwood market

Maarit Ronnila
Anne Toppinen

HELSINGIN TUTKIMUSKESKUS – HELSINKI RESEARCH CENTRE

METLA

METSÄNTUTKIMUSLAITOKSEN TIEDONANTOJA 662, 1997
THE FINNISH FOREST RESEARCH INSTITUTE, RESEARCH PAPERS 662, 1997

Testing for oligopsony power in the Finnish pulpwood market

Maarit Ronnila
Anne Toppinen

HELSINGIN TUTKIMUSKESKUS – HELSINKI RESEARCH CENTRE

Maarit Ronnila & Anne Toppinen. 1997. Testing for oligopsony power in the Finnish pulpwood market. Metsäntutkimuslaitoksen tiedonantoja 662. Finnish Forest Research Institute, Research Papers 662. ISBN 951–40–1592–4, ISSN 0358–4283. 28 p.

In this study we test for oligopsony power of the pulp industry over the Finnish pulpwood market 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 have on the average been competitive during the period. 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: roundwood market, pulp industry, oligopsony, flexible functional form

Yhteenveto:

Ostajapuolen markkinavoiman testaaminen Suomen kuitupuumarkkinoilla

Puumarkkinoiden rakenne on Suomessa epäsymmetrinen, vähän suuria ostajia suhteessa pieniin myyjiin. Ostajien keskittyminen on metsäteollisuuden yritysfuusioiden takia viimeisen vuosikymmenen aikana lisääntynyt. Raakapuumarkkinoiden rakenne viittaa epätäydelliseen kilpailuun markkinoilla. Sitä, tukeeko markkinahintojen määräytyminen epätäydellisen kilpailun oletusta ei ole Suomea koskevalla aineistolla tutkittu vaan aiemmissa empiirissä malleissa on pääsääntöisesti lähdetty oletuksesta etta kantohintojen muodostumista kuvaa kilpailevien markkinoiden malli. Tällöin puun kysyntä ja tarjonta määräävät sekä markkinahinnan että vaihdetun puumäärän.

Taloustieteessä markkinaa, jolla on paljon myyjiä ja vähän ostajia kutsutaan oligopsoniksi. 1980-luvulle asti toimialan taloustieteessä vallinnut Structure-Conduct-Performance-paradigma (SCPP) perustui pitkälti markkinoiden rakenteeseen kilpailua ilmentävänä tekijänä. Nykyisin vallalla oleva toimialan taloustieteen suuntaus, niin kutsuttu New Empirical Industrial Organization (NEIO) sen sijaan painottaa markkinoiden ekonometrista analyysia kilpailullisuuden tutkimisessa. Empiirisissä oligopolimalleissa estimoidaan ekonometriseen malliin parametri, joka kuvaa toimialan keskimääräistä markkinavoimaa, ja testataan sen ominaisuuksia tilastollisesti.

Tässä tutkimuksessa Suomen kuitupuumarkkinoihin sovelletaan ns. duaalilähestymistapaa (Appelbaum 1982), jossa teollisuuden oligopsonivoimaa arvioidaan estimoimalla tuotantopanosten kysyntäyhtälösysteemi ja testaamalla onko kuitupuun rajatuottavuus ollut markkinahintaa korkeampi. Jos markkinahinta on alhaisempi kuin panoksen rajatuottavuus, on tämä osoitus teollisuuden käyttämästä markkinavoimasta. Aineistona on toimialatason aikasarja-aineisto vuosilta 1965–94.

Käytettäessä oletusta että teollisuuden markkinavoima on vakio yli ajan saadaan tulokseksi se että kuitupuun hinta Suomessa on ollut keskimäärin lähellä kilpailevien markkinoiden hintatasoa. Sen sijaan estimoitaessa ostajien markkinavoimaa sahateollisuuden hakkeen hinnan suhteen saadaan viitteitä epätäydellisestä kilpailusta markkinoilla. Yhtenä syynä siihen, ettei metsäteollisuus olisi pystynyt hyödyntämään rakenteesta johtuvaa markkinavoimaa kuitupuumarkkinoilla, arvioidaan olevan hintaodotusten keskeisen aseman puun tarjonnassa. Mikäli metsänomistaja odottaa kantohintojen nousevan, hän voi lykätä myyntipäätöstään, jolloin toteutuva markkinahinta lähenee kilpailevien markkinoiden tasoa. Hakemarkkinoilta tällainen mekanismi puuttuu, sillä itsenäinen sahateollisuus on varsin riippuvainen sivutuloistaan hakkeen myynnistä.

Asiasanat: raakapuumarkkinat, selluteollisuus, oligopsoni, joustava funktiomuoto

Authors: Maarit Ronnila, Helsinki School of Economics, Runeberginkatu 14-16, 00100 Helsinki, tel. +358 9 4313 8277, email: ronnila@hkkk.fi and Anne Toppinen, Finnish Forest Research Institute, Unioninkatu 40 A, 00170 Helsinki, +358 9 8570 5726, email: toppinen@metla.fi.

Publisher: Finnish Forest Research Institute

Approved by Matti Kärkkäinen, Research Director, 25.11.1997

Distribution: Finnish Forest Research Institute, Unioninkatu 40 A, 00170 Helsinki, Finland, tel. +358 9 857 051, fax. +358 9 625 308.

Acknowledgements:

We thank Jari Kuuluvainen, Markku Kallio, Lauri Hetemäki, Pekka Ilmakunnas, Pertti Haaparanta and Markku Ollikainen for useful discussions. The usual disclaimer applies.

1. Introduction

In recent decades both stumpage prices and wood quantities in the Finnish roundwood market have fluctuated widely over the business cycle. The market is characterized by a pronounced structural asymmetry and a small number of wood buyers, in contrast to the over 300 000 nonindustrial private forest owners.[1] 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. For pulpwood, this competitive fringe does not exist. The large forest industry companies also import a substantial amount of pulpwood to Finland, roughly one sixth of the total consumption of industrial roundwood in 1996.

Due to increased buyer concentration, the Finnish roundwood market has often been suspected of being imperfectly competitive. However, most econometric models of Finnish sawlog and pulpwood markets have assumed competitive behaviour and have described the market quite well (see e.g. Kuuluvainen et al. 1988, Hetemäki and Kuuluvainen 1992, Toppinen and Kuuluvainen 1997). Empirical evidence on testing the market being competitive 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 pulpwood market, the buyer side may have market power over the suppliers of wood. This market power would result in a wood price level lower than that in a

---

[1] Between 1978 and 1991 a nationwide collective bargaining system including representative organisations of the forest industry and private forest owners set recommendations for stumpage prices (and starting from 1984 also for wood quantities) from private forests for each felling season. Due to developments in the economic environment, more precisely the new competition law in 1992, and the fact that Finland joined the EU in 1994, this bargaining system was prohibited due to its noncompetitiveness. Currently, individual forest industry companies and representatives of forest owners meet to discuss on stumpage price expectations for the next felling season. On empirical results based on the game-theoretic bargaining approach in pulpwood price and demand determination, see however Koskela and Ollikainen (1996).

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 pulpwood exceeding the market price for pulpwood. If buyers act collectively as a purchasing cartel, the market could even function as a monopsony. If there is oligopsony power in the pulpwood market, it could mean a welfare transfer from suppliers to buyers of wood, and it could 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 Finnish pulpwood market. 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 pulpwood price from the value of its marginal product is statistically estimated. The estimable factor demand system used 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 is treated as exogenous to industry.

2. 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, i.e. 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.[2]

---

[2] Appelbaum (1979) also presents a test for monopolistic behaviour through estimating and testing for the significance of the markup term using the *t*-test. The null hypothesis is the existence of a competitive market, and thus a non-zero markup term indicates that competition can be rejected.

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 Scroeter (1988) and Scroeter and Azzam (1990) for agricultural product markets. Input market distortions are considered e.g. by Just and Chern (1980), Love and Murningtyas (1992), 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. electricial 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 indicated a competitive pulpwood market under a constant degree of market power, but a noncompetitive pulpwood market under a variable degree of market power[3]. Murray (1995) studied market power in both the pulpwood and sawlog markets in the U.S. He modelled 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, and accepted competitive behaviour both in the input markets for wood and pulp and the output markets for sawnwood and paper products.

---

[3] Estimates of a strongly time-varying conjectural elasticity term in Bergman and Brännlund (1995) point to an unstable cartel situation with phases of strong cartel under weak pulp markets and perfect competition under strong pulp markets, which is an intuitively plausible explanation of the cyclical wood markets.

3. The model and econometric specification

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

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

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_m^i 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

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

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_m^i and $\tilde{x}^i$. Denoting the output price by w_p, the problem of firm i is:

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

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 formed as a linear aggregate of the individual firm's shadow price variable profit functions:

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

where *q(.)* is the industry equilibrium output, and x_m and $\tilde{x}$ are the industry equilibrium inputs with (shadow) prices $\mathrm{w_m}(1+\theta\gamma)$ and $\tilde{w}$ respectively. Applying Hotelling's Lemma in terms of shadow prices to equation (7), the output supply and input demand equations for the industry can be solved respectively as[4]

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

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

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

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 one output, 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 the estimable equations as a fixed input. In an alternative model specification, we follow Murray (1995) and experiment with the assumption of a quasi-fixed wood input, although we argue that it is *a priori* more reasonable to assume that wood is a

---

[4] 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 $w_m^*(1+\theta^i\gamma)$

flexible input, compared e.g. with labour. We based the estimable system 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 $(1 + \gamma\theta)$, 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

$$(11) \quad \Pi(w^s,Z)=\sum_{i}^{m}\sum_{j}^{m}\beta_{ij}(w_i^s w_j^s)^{0.5}+\sum_{i}^{n}\sum_{j}^{n}\mu_{ij}Z_iZ_j+\sum_{i}^{m}\sum_{j}^{n}\phi_{ij}w_i^s Z_j,$$

where $\beta_{ij,}\, \mu_{ij}, \phi_{ij}$, as well as the parameters γ and θ in the shadow price of wood, are estimable parameters. 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 the estimable equations for output q and for the demand for variable factors x_i.

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

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

---

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^*.

For fixed inputs, i, we obtain equations for their shadow prices, λ_i:

$$(14) \qquad \lambda_i = \sum\nolimits_j^m \phi_{ij} w_j^s + \sum\nolimits_j^n 2\mu_{ij} Z_j .$$

Assuming roundwood input to be freely adjustable, the estimable system consists of equation (12) for pulp output and equations (13) for wood and labour input. When the wood input is assumed to be quasi-fixed, the shadow profit equals the observed actual profit and the estimable system consists of equation (11) for profit, equation (12) for pulp output, and equation (13) for labour input. The shadow price for wood can then be calculated from the obtained parameter estimates using equation (14).

When 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. For domestic pulpwood, simultaneous estimation of the supply elasticity was attempted. But due to convergence problems caused by nonlinearities in the model system and to the wrong sign obtained for the pulpwood supply elasticity, this approach could not be used.[5] Moreover, 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. However, it is justifiable to assume that the supply elasticities of all these alternative sources of the wood input are finite. Earlier roundwood market studies that assume competitive markets, suggest that the elasticity of the stumpage price of pulpwood with respect to supply (i.e. the inverse price elasticity) lies between 1.0 and 2.0 (e.g. Kuuluvainen et al. 1988, Toppinen & Kuuluvainen 1997).

Nevertheless, since our purpose was to test the pricing rule, we chose to treat the mark-down term for the wood price $(1 + \gamma\theta)$ as a single parameter, χ, in our empirical model. Therefore, an estimate for χ that is greater than 1 indicates deviation from competitive wood pricing. 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 $L \equiv \chi - 1 = \gamma\theta$.

---

[5] One reason for these estimation problems could be the fact that private forest owners account for only about a half of the roundwood quantity used in the Finnish pulp industry and thus the utility maximing behavioural model for NIPFs is not well suited to our case.

4. Time series data

The model was estimated using annual data for Finland for the period 1965 to 1994 (for graphs of the main variables see Appendix 1). In measuring wood price and wood input,a number of factors should be taken into account. Most importantly, the pulp industry not only uses domestic pulpwood, but also imported pulpwood and wood chips purchased from the sawmilling industry. Imported roundwood comes mainly from Russia, and up to late 1980s a large share of wood imports was based on bilateral trade agreements between Finland and the former Soviet Union. This suggests that wood imports have not necessarily always been adjustable to actual business conditions in the forest industry.

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 substitutes for roundwood, difference in the quality of the 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. Price differences 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.[6] But 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. Despite the quality differences, one would expect that the price difference between roundwood and wood chips would have been relatively stable, but this has not been the case. The cost of domestic roundwood has always exceeded the price of wood chips.

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 as obtained from the Industrial Statistics. 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 had to use 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 low quality of the wood chip price data must be borne in mind when comparing results from alternative models.

Due to data limitations, we assume that although the quality of chips and roundwood may vary, wood inputs from the three different sources are (perfect) substitutes. The wood input used in the study is therefore the total amount of domestic and imported primary pulpwood, and wood chips consumed in the pulp industry. As to prices, we will experiment with prices of both wood chips and domestic roundwood as a representative wood price. The firms in the forest industry are assumed to use market prices as a basis for their internal transfers of wood and chips.

---

[6] Correlations between all quantity series of wood input and pulp output are high. The total wood input, including pulpwood and wood chips, has a correlation coefficient of 0.99 with pulp output. The correlation

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, accounting also for the greater knowhow of typical labour inputs in the pulp mills today. 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. 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. However, due to high correlation between the capital stock series for the pulp and paper industry and for the pulp industry alone, the choice between the two capital stock values should not make a difference in estimation.

---

between pulp output and domestic pulpwood input alone have a correlation of 0.73, while the correlation between pulp output and the sum of domestic and imported roundwood is 0.94.

5. Estimation results

The model was estimated using Zellner's iterative seemingly unrelated regression method. All the equations were estimated in a stochastic form with additive disturbance terms. We considered two alternative cases: the total wood input being flexible (Models A, B, C) and the total wood input being quasi-fixed (Model D). In Model A imperfect competition was allowed in the pulpwood market, while in Model B it was allowed in the market for wood chips. To avoid having the estimable parameter appear under the square root sign, we introduced the estimable parameter for $\sqrt{\chi}$, and used its square as χ in our estimations.

Let us first consider the models with flexible wood input since we think it is the more realistic assumption in modelling demand for wood. First we 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 the estimable system (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 Cobb-Douglas technology is not a good description of the wood pulp industry.

Table 1. Parameter estimates for alternative iterative seemingly unrelated regression models. (*t*-values in parentheses) The subscripts are: *q* for pulp, *l* for labor, *w* for wood, *T* for technological change, and *K* for capital.

	Pulpwood price	Residual wood price	Pulpwood price	Wood quasi-fixed
	A	B	C	D
	Imperfect competition	Imperfect competition	Perfect competition	
	χ=free	χ=free	χ=1	
$\sqrt{\chi}$	0.99 (6.53)	1.21 (7.51)	–	–
β_{qq}	6.75 (6.40)	5.96 (9.28)	5.90 (10.79)	–0.70 (–2.84)
β_{ll}	–29.87 (–5.50)	–20.12 (–4.23)	–27.42 (–5.53)	–23.4 (–5.52)
β_{ww}	–9.89 (–1.98)	–12.50 (–3.71)	–4.48 (–1.53)	
β_{ql}	–2.36 (–4.48)	–3.29 (–4.95)	–2.43 (–4.64)	–1.63 (–3.55)
β_{wl}	7.16 (4.75)	9.22 (5.57)	6.71 (4.64)	
β_{qw}	–4.96 (–2.46)	–3.29 (–3.95)	–5.27 (–8.36)	
μ_{TT}	–	–	–4.75 (–2.88)	12.22 (2.13)
μ_{TK}	–	–	0.00 (4.28)	0.01 (2.24)
ϕ_{qK}	0.00 (0.16)	0.00 (0.12)	0.00 (1.66)	0.00 (2.13)
ϕ_{qT}	0.14 (5.11)	0.15 (5.66)	0.12 (4.75)	0.01 (1.34)
ϕ_{lK}	–0.00 (–7.13)	–0.00 (–7.34)	–0.00 (–7.80)	–0.00 (–3.68)
ϕ_{lT}	1.04 (10.26)	0.90 (10.07)	1.03 (11.05)	0.51 (5.63)
ϕ_{wT}	–0.55 (–4.39)	–0.63 (–5.26)	–0.44 (–3.97)	–3.82 (–2.46)
ϕ_{wK}	–0.00 (–0.22)	–0.00 (–0.36)	–0.00 (–1.85)	–0.01 (–9.43)
ϕ_{wq}				0.24 (26.35)
ϕ_{wl}				0.27 (3.65)
Equation: Π Adj. R^2(DW)	–	–	0.79 (0.59)	0.86 (0.98)
Equation: Q Adj. R^2(DW)	0.78 (0.58)	0.78 (0.63)	0.77 (0.53)	0.99 (1.02)
Equation: $-X_W$ Adj.R^2(DW)	0.73 (0.58)	0.72 (0.62)	0.71 (0.52)	–
Equation: $-X_L$ Adj. R^2(DW)	0.97 (0.70)	0.97 (0.91)	0.97 (0.66)	0.95 (0.71)

In model A a significant estimate, 0.99, is obtained for $\sqrt{\chi}$, and the Wald test supports the restriction $\sqrt{\chi}=1$ with a probability of 0.97. Hence, the result suggests that the pulpwood market has been competitive if the wood price at the margin has been determined in the domestic pulpwood market. 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 estimable 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 similar to those of the model A, as can be seen from Table 1.[7]

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[8]. The obtained Wald-test probability value for restriction $\sqrt{\chi}=1$ was low, only 0.19.

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 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 own-price elasticity of pulp supply was 0.15. Labour input was found to be a complement for wood input, in contrast to Hetemäki (1990), who found that labour was a substitute for wood in 1960–86.

---

[7] In order to examine in more depth the substitution between roundwood and wood chips, we experimented with a model where either pulpwood input or wood chip input alone represented the flexible wood input. The estimates for χ were less than one, which is theoretically incorrect (0.42 in the first case and 0.90 in the latter case). When the separate input demand equation for wood chips was included in the system in addition to pulpwood input demand, none of the parameters relating wood chips to other inputs and output was significant. Separating the inputs thus clearly weakened model performance.

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

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

	Pulp price	Wood cost	Labor cost	Capital stock	Technology level
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	0.28

It is worth noting, however, that the models suffer from residual autocorrelation, as indicated by the low 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, the adjusted R^2 values were markedly higher in all the equations of Model A (estimation results in Appendix 2). Residual autocorrelation was slightly reduced as indicated by the rise in Durbin-Watson statistics. Most interestingly, the inclusion of dummies increased the markdown term in the model A, where $\sqrt{\chi}$ received an estimate of 1.17.

In models A and B the potential markdown was assumed to be constant over the examined time horizon. This assumption is rather restricting and, in addition to the static nature of the estimable system, it is one of the potential reasons for the diagnostic problems with the system. Unfortunately, our experiments using the time-varying markdown parameter, consisting of exogenous variables as in Bergman & Brännlund (1995), failed to converge, and we had to settle for the constant index of market power.

However, our experiment with the assumption of quasi-fixed wood input, following Murray (1995) gives some insight for the question of how the market power has varied over time, as the estimates for the shadow prices of wood can be calculated from the estimated parameters. The results are reported in connection with Model D. Now labour is the only variable input in the model. This is a very extreme assumption, and we used the value of wood costs as an additional proxy for the other variable costs than labour to be able to obtain meaningful results. Thus, we substracted the value of wood costs from the calculated variable profit in the industry and estimated a behavioural profit function together with equations for pulp supply and labour input. Due to linear aggregation of the individual producers, the coefficients μ_{ww} for wood and μ_{KK} for capital in Equation (11) were restricted to be zero. For consistency in aggregating the firms' profit functions to form the industry profit function, it had to be assumed that the shadow prices for the fixed inputs do not depend on the level of the fixed inputs nor thus on the allocation of these inputs between the firms.

The estimation results from Model D indicated better in-sample fit for the pulp output and profit equations than in Model A. For the output equation this can be expected, because the total wood input was among the variables explaining pulp output, and these two variables are almost one-to-one correlated. The parameter estimates that were obtained from the three equations were used to calculate shadow prices for wood input (Figure 1).

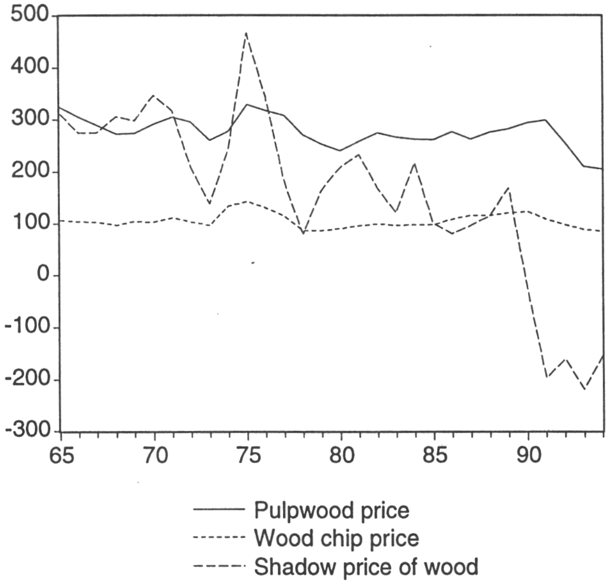


Figure 1. The prices of pulpwood and wood chips and the estimated shadow price of wood in pulp production (wood as a quasi-fixed input from Model D) in 1965–94, FIM/m^3.

The resulting shadow price was below the pulpwood price except in four early periods, while the wood chip price seemed to form a lower bound for the shadow price estimates. This provides support for the assumption that wood chips input determines the shadow price for wood in Model B. However, during the 1990s the calculated shadow price was negative, which clearly reduces the reliability of Model D.

6. Conclusions

In this paper we tested for deviations from competitive pricing of pulpwood 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 pulpwood price. Since we deal with the aggregate pulpwood market and time series data, noncompetitive pulpwood pricing at the local level or over shorter time periods is still possible.

Most parameters of the models were statistically significant, and the signs for own-price elasticities in the models were agreed with the theory. However, the estimated models suffered from residual autocorrelation, and the results were sensitive to having all data points of the observation period included. Therefore one must be cautious with the conclusion regarding the degree of competition in the pulpwood market. Further work, preferably using other modelling approaches, is necessary to gain more confidence in the robustness of these results.

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 support 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, in previous studies on the Finnish wood markets, price expectations have been found to 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.

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.

Koskela, E. & Ollikainen, M. 1996. A game-theoretic model of timber prices with capital stock: An empirical application to the Finnish forest sector. VATT Research paper 132.

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.

Love, H.A. & Murningtyas, E. 1992. Measuring the degree of market power exerted by Government Trade Agencies. *American Journal of Agricultural Economics*. Vol 74, 546–555.

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.

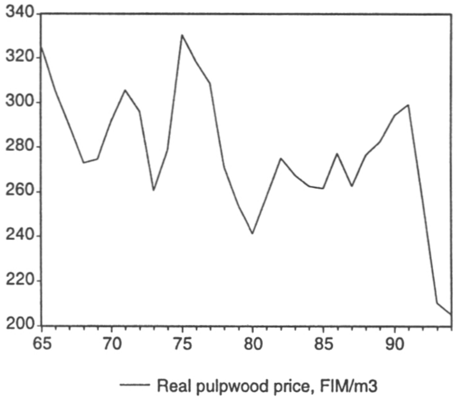
Slade, M. 1995. Empirical games: the oligopoly case. *Canadian Journal of Economics*. Vol 28, 368–402.

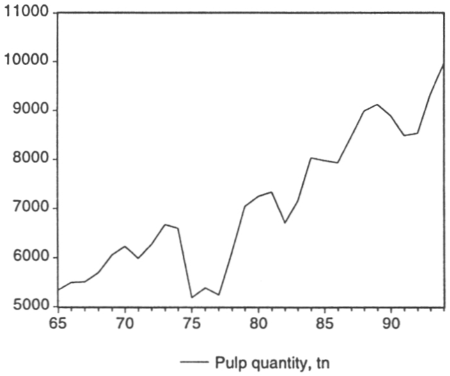
Tirole, J. 1988. The Theory of Industrial Organization. MIT Press, Cambridge. 479 p.

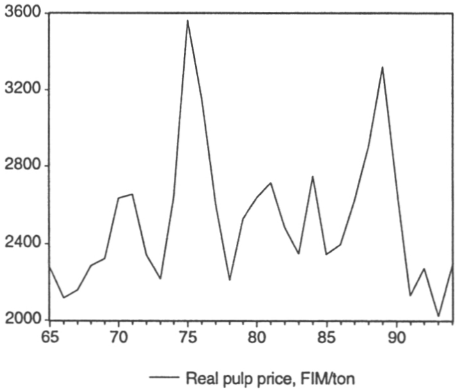
Toppinen, A. & Kuuluvainen, J. 1997. Structural changes in the Finnish sawlog and pulpwood markets. *Scandinavian Journal of Forest Research.* (forthcoming)

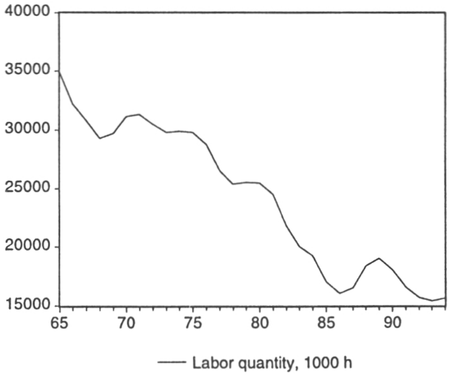
Wann, J. & Sexton, R. 1992. Imperfect competition in multiproduct food industries with application to pear processing. *American Journal of Agricultural Economics*. Vol 74, 980–990.

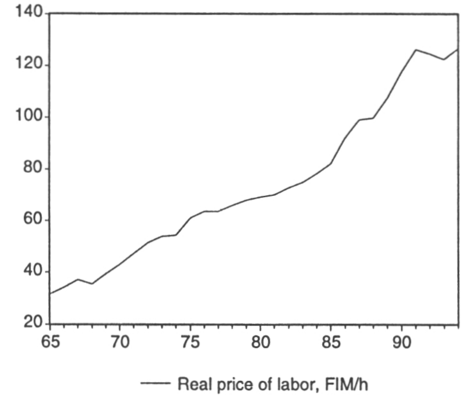
Appendix 1. Graphs of main variables in the Finnish pulp industry, 1965–94.











Appendix 2. Parameter estimates for Model A with dummy-variables included for period 1975–77 (t-values in parentheses). The subscripts are: *q* for pulp, *l* for labour, *w* for wood, *T* for technological change, and *K* for capital.

	Model A Imperfect competition + Dummy variables
$\sqrt{\chi}$	1.17 (15.56)
β_{qq}	8.36 (8.39)
β_{ll}	–27.67 (–5.45)
β_{ww}	–0.28 (–0.06)
β_{ql}	2.59 (4.92)
β_{wl}	6.05 (4.35)
β_{qw}	–8.96 (–4.47)
ϕ_{qK}	0.00 (2.61)
$D75_q$	–1.97 (–6.04)
$D76_q$	–1.71 (–5.47)
$D77_q$	–1.76 (–5.77)
ϕ_{qT}	0.10 (5.64)
ϕ_{lK}	–0.00 (–7.25)
ϕ_{lT}	1.01 (10.58)
ϕ_{wT}	–0.33 (–4.44)
ϕ_{wK}	–0.00 (–2.66)
$D75_w$	8.28 (6.24)
$D76_w$	7.44 (5.86)
$D77_w$	7.11 (5.72)
Equation: Q	
Adj. R^2 (DW)	0.93 (1.09)
Equation: $-X_W$	
Adj.R^2 (DW)	0.92 (1.14)
Equation: $-X_L$	
Adj. R^2 (DW)	0.97 (0.68)

ISBN 951-40-1592-4
ISSN 0358-4283
Hakapaino Oy 1997