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THE FINNISH ROUNDWOOD MARKET: An econometric analysis*

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The present study investigates the determination of the aggregate supply of and demand for saw logs and pulpwood in Finland using annual data from 1965 to 1985. Raw material is purchased in competitive markets from private nonindustrial forest owners. The equilibrium assumptions seem to work rather well in both markets, in spite of the fact that, particularly in the pulpwood trade, recommended stumpage price agreements have been concluded for most of the years. Both supply and demand react to prices, and cross elasticities of supply between saw logs and pulpwood are positive or zero. When only pulpwood originating from thinning stands is used as the dependent variable in the pulpwood trade, supply and demand elasticities for pulpwood increase and cross elasticity of pulpwood supply with respect to the price of saw logs becomes negative.

1. *Introduction*

Research on the factors influencing the demand for and supply of wood and its price determinants has for long been surprisingly sparse when compared to the significance of the roundwood market and the discussion that it has attracted. It was not until the beginning of the 1980s that econometric research in this field clearly began to increase both in Finland and in Sweden. In Finland, several studies examined either a certain segment of the market, or the short-term supply of and demand for of various types of timber as a whole. Korpinen (1981) and Kuuluvainen (1982, 1986) focused solely on the saw log market while Tervo (1984, 1986) considered aggregated supply of and demand for various types of timber by owner groups. In Sweden, Brännlund et al. (1985) examined the saw log and pulpwood markets separately, assuming the saw log market to be competitive and the pulpwood market to be a monopsonistic market.

This article presents the theoretical framework of a short-term econometric model of the Finnish saw log and pulpwood markets and the results obtained so far. The aim is to throw light on the significance of various demand and supply factors for variations in

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roundwood trade and to create a basis for further work in the development of a short-term forecasting system.

The markets for saw logs and pulpwood are examined separately. In the present study we seek to find out whether saw log and pulpwood markets can be described using a simultaneous equilibrium model. In this kind of model, the price is determined through interaction between supply and demand, and adjusts flexibly to bring the market into equilibrium in each period (felling season). A competitive market which reaches equilibrium is *a priori* assumption, not a hypothesis which we attempt to test directly here. The assumption implies that no significant functional differences are expected to prevail between the saw log and the pulpwood markets (which may sound surprising). The rationale for this will be discussed in more detail in the theoretical section.

The main reason for considering the saw log and pulpwood markets separately is the possibility of information loss in aggregated data. As variations in the submarkets may be different both as regards to rhythm and amplitude, combining traded quantities could conceal variation to a significant degree. On the other hand, the interaction of the partial markets, for instance the cross effects of prices, is in itself an interesting question. Consequently, the supply equation for pulpwood includes the stumpage price of saw logs, and correspondingly, we also investigate the effect of pulpwood price on the supply of saw logs. Furthermore, the study seeks to take into account the fact that part of pulpwood originates from sawtimber stands and part from (thinning) stands consisting mainly of pulpwood trees. This is because we expect that the reactions of pulpwood supply originating from different sources to the stumpage price and the cross effects of the saw log price on the stumpage price are different (for more detail, see Section 2.2.).

In contrast to early econometric work (e.g. Korpinen (1981)), this study uses actual quantities traded (quantities bought and sold) as endogenous volume variables. Market fellings by no means adequately describe traded quantities in the short term (see Kuuluvainen et al. (1981)), primarily because of considerable standing inventories of roundwood.

2. *Theoretical background of the roundwood market model*

2.1. *Demand functions of a representative firm*

Firms in the sawmill and pulp and paper industries are assumed to sell their final products on competitive export markets at given prices p^s_t (sawnwood) and p^k_t (pulp and paper). Forest industry output can be described using the production function

$$(1) \quad y_t = F\,(l_t,\ c_t)$$

where l_t is labour input and c_t is the wood raw-material input needed to produce an amount y_t of the final product. Ignoring decisions on the holding of raw-material inventories and the uncertainty contained in short-term production decisions, the profit-maximizing problem of the representative firm can be used to derive short-term demand functions for saw logs and pulpwood (cf. Johansson & Löfgren (1985)):

$$(2) \quad ci^D_t = ci^D\,(\underset{+}{p^i_t},\ \underset{-}{q^i_t},\ \underset{?}{w^i_t})$$

where

ci^D_t = demand for roundwood type i
p^i_t = export price of final products
q^i_t = stumpage price of roundwood type i
w^i_t = unit labour cost in industry
index i = s for saw logs or sawnwood,
k for pulpwood or products of the pulp and paper industry
t = year

In equation (2), the expected direction of effect, i.e. the sign of the coefficient is shown below each independent variable. The sign of the wage variable is uncertain because it cannot be deduced *a priori* whether roundwood is a technical complement or a substitute for labour input. Empirical results have been contradictory, some studies showing that labour and roundwood inputs are complements (see Merrifield and Haynes (1983); Sherif (1983); Merrifield and Singleton (1986)) and some that they are substitutes (see Martinello (1987); Wibe (1987); Newman (1987)).

2.2. *Roundwood supply by private nonindustrial forest owners*

The share of roundwood from private nonindustrial forests in the total use of wood by the forest industry was about 74—77 per cent on average over the period examined. Other sources of supply include state forests, companies' own forests and wood imports (these supply components have been examined in more detail in Tervo (1986)). In this study we have implicitly assumed that the supply of roundwood from outside private forest does not affect the elasticity coefficients to be estimated. Although this assumption may be problematical for wood coming from companies' own forests and wood imports, it seems likely that any effects the assumption might have on the estimation results are marginal (the share of these supply categories in the total use of wood by the forest industry was 14—17 per cent on average over the period examined).

Brännlund et al. (1985), among others, used the linear forest model (Johansson & Löfgren (1985)) as a theoretical background for the supply equation. In this case, the independent variables are roundwood (delivery) prices, harvesting costs, the level of interest rates and expectations about the future values of these variables. This model is based on the assumption of a perfect capital market, according to which it is possible to both deposit and borrow funds without limit at the given market rate of interest. However, the empirical work presented here does not include interest rates variables. These have not yielded clear results in empirical experiments (see e.g. Brännlund et al. (1985); Ovaskainen (1987); Hultkrantz (1987); Hultkrantz & Aronsson (1988)). Furthermore, some Finnish forest owners have probably encountered liquidity constraints owing to the selective credit rationing that has occurred in the Finnish financial markets. Consequently, the overall effect of the interest rate is indeterminate *a priori*.[1] For these reasons, the variable was omitted. On the other hand, it can be shown, that under credit rationing, forest owners' non-forestry income does have a negative effect on supply (see Ollikainen (1987); cf. also Koskela (1988)).

In Finland, the bulk of roundwood trade consists of stumpage sales. As regards delivery sales, harvesting and transport costs are assumed to be so stable in comparison to stumpage prices in the short run that they can be ignored. Thus, stumpage prices are used for the price received by the forest owner for his wood, on the one hand, and as roundwood unit costs for industry, on the other. For empirical work, we arrived at implicit supply functions of the form

$$\text{(3a)}\quad cs^S_t = cs^S(\underset{+}{q^s_t},\ \underset{-}{q^{es}_t},\ \underset{?}{q^k_t},\ \underset{-}{m_t})$$

and

$$\text{(3b)}\quad ck^S_t = ck^S(\underset{+}{q^k_t},\ \underset{-}{q^{ek}_t},\ \underset{?}{q^s_t},\ \underset{-}{m_t})$$

where

ci^S_t = supply of roundwood of type i

q^{ei}_t = expected stumpage price for roundwood of type i

q^i_t = stumpage price

m_t = non-forestry income

index i = s, k as in equation (2).

In addition to the prevailing price, each supply equation contains the expected price of the type of roundwood in question. If the expected price in the future period is low, part of the timber that would otherwise have been left for the following period is sold in the present period. By contrast, a higher expected price implies that it is worth postponing part of timber sales until the following period.

The supply equations take into account possible interactions between the supply of saw logs and pulpwood. In order to measure the cross effects of prices, the saw log supply function also includes the pulpwood price and, correspondingly, the pulpwood supply equation includes the saw log price. An unambigious hypothesis on the sign of the cross elasticity cannot be put forward, however, because part of pulpwood is obtained from sawtimber stands in a fixed ratio to logs, and part from stands dominated by pulpwood. It can be expected that the cross elasticity with re-

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[1] *Ollikainen (1987) shows in a two-period model that a rise in the interest rate level reduces wood supply by a credit rationed forest owner (in other words, the effect of the interest rate is the opposite to that in the non-rationed case).*

spect to the price of saw logs is formed differently for total pulpwood and for pulpwood that comes from thinnings only. In the former case, it can be expected that an increase in the price of logs will at the same time increase the supply of pulpwood and, correspondingly, an increase in the price of pulpwood may also augment the supply of saw logs. In the latter case, on the other hand, a higher log price may lead to a reduced supply of pulpwood, if the now relatively more profitable final cuts crowd out part of thinnings.

2.3. Short-run market equilibrium

In studies on the market for saw logs, it has traditionally been assumed that the market is competitive and reaches equilibrium in each period. On the basis of the structure of purchasers, the assumption of a competitive market seems justified, as the number of buyers engaged in log trading has traditionally been large. On the other hand, for example, in the early 1980s there was discussion on the excess demand situation in the roundwood market, i.e. disequilibrium, which was said to have restricted output in the sawmill industry.

The equilibrium assumption implies the notion of a competitive market in which numerous firms function as »price takers», i.e. no single firm can significantly influence the market price. The price is thought to be determined endogenously at the level of the entire market, and to adjust flexibly to changes in supply and demand as well as to expectations, bringing the market into equilibrium in each period of time. At the equilibrium price q^*, the quantities demanded and supplied are equal, i.e. $c^D = c^S = c^*$ (Fig. 1a).

The results obtained by Kanniainen and Kuuluvainen (1984) on the time series analysis of saw log prices support this assumption, as no clear indications of imperfect competition or other price rigidities were detected. Brännlund (1988) explicitly tested the equilibrium vs. disequilibrium hypotheses in the Swedish saw log market. The results showed that the disequilibrium model was only slightly better than the equilibrium one, although claim about the existence of excess demand in the roundwood market had been very much at the centre of the Swedish discussion as well.

In the present study, however, the equilibrium assumption also applies to the pulpwood market, the treatment of which varies in different studies. Newman (1987), who studied the softwood stumpage market in the southern United States, used the same structure as in this study. By contrast, Brännlund et al. (1985) considered the pulpwood market as a monopsonistic market in which the price is exogenous. In another study, Brännlund (1988) used the same assumption to examine the effects of imperfect competition.

At least two reasons may be put forward to explain why the pulpwood market can be expected to differ from the saw log market. First, the number of pulpwood users has been clearly smaller and, furthermore, it has been claimed that buyers have acted in cooperation.

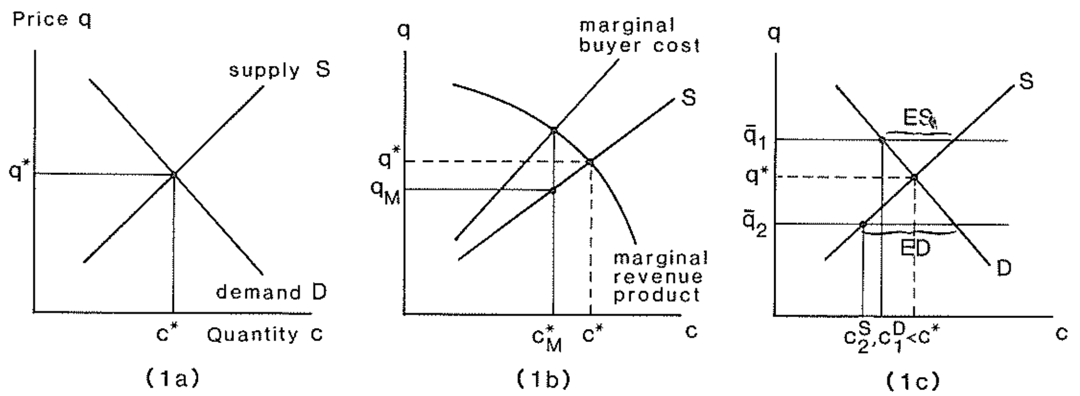

Figure 1. Determination of traded quantity and price of input in a competitive market (1a), in the case of one buyer, i.e. monopsony (1b) and in a fixed-price market resulting, for example, from a binding price agreement (1c).

This kind of market could in its extreme form be characterized as a monopsony, or a one-buyer situation (Fig. 1b). The monopsony buyer makes a profit-maximizing production decision and sets the wood raw-material price q_M on the basis of the known reactions of the sellers (expected supply curve) at such a level that the optimal purchase target c_M^* is achieved (e.g. Johansson & Löfgren (1985)).

Secondly, in the case of pulpwood, nation-wide price recommendation agreements have been concluded for most felling seasons since the mid-1960s, in contrast to saw logs (only from felling season 1978/79 onwards). If the price agreement holds, i.e. the price is fixed for the purchasing period in question and trading takes place on a voluntary basis, the quantity traded will be the minimum of the quantities demanded and supplied (c_2^D or c_2^S in Fig. 1c). If the price cannot adjust and the agreed price differs from the hypothetical equilibrium price q*, the market will remain in disequilibrium, in which case either the buyer or the seller is »off his demand or supply curve». If the contract price is below the equilibrium price q* ($\overline{q_2}$), excess demand (ED) exists and if above ($\overline{q_1}$) excess supply exists (ES; for more details see eg. Brännlund (1988); Kuuluvainen (1986)).

In spite of these considerations, there are grounds for applying the simultaneous equilibrium model to the pulpwood market as well. First, concentration in the market does not necessarily lead to monopsony (oligopsony) pricing, since the market structure is neither a sufficient nor a necessary condition for certain behaviour. Direct conclusions on competition and price formation prevailing in the market cannot be drawn on the basis of concentration. On the other hand, despite price recommendation agreements there is reason to believe that price continues to be a real means of competition in the pulpwood trade. The agreements are recommendations and prices are adjusted for density, tree size, wood quality and haulage distance. These and other terms in the roundwood trade nevertheless allow competition between buyers. An indication of this competition has been the discussion on »price drift», i.e. deviation of the actual and the recommended stumpage prices (see Tervo (1986)).[2]

[2] *In practice, it is difficult to evaluate the size of price drift accurately, because comparable time series do not exist on agreement prices and actual prices. Stumpage prices are recommended prices for an average stand, defined in terms of the size of the stand, three size, haulage distance and density per hectare. In the data on actual stumpage prices, stands have not been separated according to the above pricing factors; rather the data on average prices of roundwood sales are volume-weighted regional average prices.*

3. *Research results*

3.1. *Estimated model and research data*

On the basis of the discussion above we specified a simultaneous short-term equilibrium model describing the saw log and pulpwood market. The model consists of demand and supply functions (4a) and (4b) for saw logs, the corresponding equations for pulpwood (5a) and (5b) and the equilibrium conditions for both submarkets (4c) and (5c).

(4a) $cs_t^D = \alpha_0 + \alpha_1 p_t^s + \alpha_2 q_t^s + \alpha_3 w_t^s + \alpha_4 cs_{t-1}$

(4b) $cs_t^S = \beta_0 + \beta_1 q_t^s + \beta_2 q_{t-1}^s + \beta_3 q_t^k + \beta_4 m_t + \beta_5 cs_{t-1}$

(4c) $cs_t = cs_t^D = cs_t^S$

(5a) $ck_t^D = \gamma_0 + \gamma_1 p_t^k + \gamma_2 q_t^k + \gamma_3 w_t^k + \gamma_4 ck_{t-1}$

(5b) $ck_t^S = \delta_0 + \delta_1 q_t^k + \delta_2 q_{t-1}^k + \delta_3 q_t^S + \delta_4 m_t + \delta_5 ck_{t-1}$

(5c) $ck_t = ck_t^D = ck_t^S$

where

cs_t^D = demand for saw logs
cs_t^S = supply of saw logs
ck_t^D = demand for pulpwood
ck_t^S = supply of pulpwood
p_t^i = export price of final products (i = s, k)
w_t^i = labour costs in industry (i = s, k)
q_t^i = stumpage price (i = s, k)
m_t = non-forestry income (relative change from previous period)

superscripts (i):

s = saw logs or sawngoods
k = pulpwood or pulp and paper industry products
α, β, γ and δ = parameters to be estimated.

The expected directions of effect of the various factors, i.e. the signs of the coefficients to be estimated, were presented above in the theoretical section. All behavioral equations include a lagged explanatory variable, the quantity traded in the previous period. In the demand equations, this variable seeks to take into account the possible effects of the adjustment costs of production and raw-material acquisition through partial adjustment. In the supply equations, on the other hand, the lagged volume is linked to the assumption of forest owners' adaptive stumpage price expectations:

$$(8)\quad q_t^e - q_{t-1}^e = \mu\,(q_{t-1} - q_{t-1}^e),\ 0 < \mu \leq 1$$

where the superscript e refers to expectations. A part of the actual expectations error is assumed to be taken into account when forming expectations about prices in the next period. From this we arrive at the form to be estimated, in which price expectations are represented by the price and the quantity traded in the previous period. Because supply and price expectations are negatively correlated, lagged prices should receive negative signs in the estimation.

In the estimation, nationwide annual time series from the period 1965—1985 were used. All price variables are real. They were deflated by the overall wholesale price index. Stumpage prices and corresponding sales from private nonindustrial forests by felling seasons were used (Tervo (1986)) as roundwood prices and traded volumes (endogenous variables). Series by felling seasons are natural here, because, for example, timber purchased in the felling season year 1984/85 was mainly used in industry in the calendar year 1985. If the observation period were shorter, it would be necessary to take standing inventories of timber into account.

Export prices are average prices of export deliveries according to the customs statistics. The export price indices have been calculated using the value and volume of exports by the sawmill industry for the heading 248.2 and as a weighted average of the headings 251, 641 and 642 for the pulp and paper industry. The time series on household disposable income is from the data of the Bank of Finland Quarterly Model of the Finnish Economy.

3.2. Estimation results

The model was estimated in a log-linear form, using the two-stage least squares method to take account of the endogeneity of the prices (2SLS, e.g. Judge et al. (1982)). Tables 1 and 2 present the estimation results of the model in which the dependent variables were the total volumes of saw logs and pulpwood. Table 3 presents the demand and supply equations for pulpwood when the dependent variable used is the quantity of pulpwood originating from thinnings. Because the explanatory variables are the same, the part of the model concerning the saw log market does not change when the quantity variable for pulpwood trade is switched. Actual quantities traded and the fitted values from the demand and supply equations of the model (i.e. the structural form) are presented in charts 1—3 in Appendix 1.

In the markets for final products and roundwood, structural changes seem to have occurred in the severe recession of the second half of the 1970s which were connected with export market developments after the energy crisis. In the 1976 recession both the demand for and the supply of roundwood differed clearly from the »normal situation». The post-recession recovery also appears to have produced adjustment reactions which could not be explained by the model specified above. The effect of these deviations was taken into account in the model by adding three dummy variables, which obtained the value zero in »normal years» and the value one in »deviation years». In the saw log model the addition of these dummies did not affect the coefficients of other variables, but the estimation of the demand equation for pulpwood did not succeed without two dummy variables. Dummy variables were not used in the equation for pulpwood originated from thinnings. An autocorrelation correction of the residuals was necessary in the pulpwood demand and supply equations.

3.3. The saw log market

The estimated demand and supply equations for saw logs (Table 1) are fairly good as far as their statistical properties are concerned. The signs of the coefficients correspond to the a priori expectations and most coefficients are

Table 1. 2SLS estimations (log linear) for the demand and supply equations for saw logs. t-statistics of the coefficient estimates are in parentheses.

Variable to be explained	Demand cs_t^D	Supply cs_t^S
Constant	—11.11	4.11
Export price p_t^s	2.81 (5.33)	
Stumpage price q_t^s	—1.34 (3.62)	0.53 (2.33)
Price expectations q_{t-1}^s		—1.34 (5.66)
Pulpwood price q_t^k		0.39 (1.93)
Income change m_t		—23.68 (2.27)
Lagged volume cs_{t-1}	0.55 (4.21)	0.38 (3.96)
Dummy 75/76	—0.67 (3.91)	—0.42 (2.95)
Dummy 77/78	—0.37 (2.13)	
Dummy 78/79		0.43 (3.62)
Coefficient of correlation R^2	0.82	0.92
Durbin-Watson statistic	2.58	1.85
Durbin's h-statistic	1.53	0.29

Table 2. 2SLS estimations (log-linear) for pulpwood demand and supply equations (total traded pulpwood).

Variable to be explained	Demand ck_t^D	Supply ck_t^S
Constant	—5.19	3.94
Export price p_t^k	0.92 (1.85)	
Stumpage price q_t^k	—0.19 (0.98)	0.59 (3.66)
Price expectations q_{t-1}^k		—1.04 (6.79)
Saw log price q_t^s		0.03 (0.13)
Income change m_t		—11.60 (1.41)
Lagged volume ck_{t-1}	0.47 (3.40)	0.16 (1.25)
Dummy 75/76	—0.73 (6.05)	
Dummy 77/78	—0.55 (5.02)	
Coefficient of correlation R^2	0.89	0.92
Autocorrelation coefficient	0.47	0.77
Durbin-Watson statistic	1.68	1.55
Durbin's h-statistic	0.88	1.18

Table 3. 2SLS estimations (log-linear) for demand and supply equations for pulpwood coming from pulpwood-dominated (thinning) stands.

Variable to be explained	Demand ck_t^{D*}	Supply ck_t^{S*}
Constant	—7.64	4.17
Export price p_t^k	1.16 (0.95)	
Stumpage price q_t^k	—0.71 (1.87)	1.55 (6.88)
Price expectations q_{t-1}^k		—1.22 (5.51)
Saw log price q_t^s		—0.88 (3.22)
Income change m_t		—13.20 (1.16)
Lagged volume ck_{t-1}^*	1.35 (6.04)	0.40 (2.24)
Coefficient of correlation R^2	0.79	0.89
Autocorrelation coefficient	—0.54	0.85
Durbin-Watson statistic	1.73	1.89
Durbin's h-statistic	2.86	0.43

also statistically significant. On the basis of the theoretical examination, the saw log demand equation should also include a variable describing labour costs. However, this variable received coefficients which were statistically clearly nonsignificant in estimation experiments. The variable was ommitted from the estimated model as it did not markedly affect the other parameters of the model. In addition to labour costs, experiments were also made with a variable describing the »ability to pay for timber», constructed as the difference between export prices and labour costs (cf. Brännlund et al. (1985)), bu the results did not correspond to expectations.

The results indicate that, for instance, the demand for saw logs is elastic with respect to the export price. The elasticity estimate 2.8 is rather high (notice, however, that the quantity traded does not increase as much as indicated by the instantaneous elasticity, since the price of wood rises as demand shifts). The cross elasticity of the supply of saw logs with respect to the price of pulpwood is statistically almost significant (at 5 % level). As expected, the coefficient shows that the supply of saw logs increases when the price of pulpwood rises. Other interesting results include the price elasticities describing the sensitivity of the reaction of buyers and sellers to price changes. According to the results, the price elasticity of demand and supply with respect to the stumpage prices are —1.3 and 0.5 respectively.

However, the absolute values of the estimates should still be treated with caution. In preliminary 3SLS estimations the price elasticity of the supply of both saw logs and pulpwood with respect to the price in the current period rose substantially, and had a greater absolute value than the lagged stumpage price. In Table 1 the negative elasticity of supply with respect to the lagged price representing price expectations, is larger in absolute terms than the elasticity with respect to the present price. The small number of observations apparently causes the weak robustness of the absolute values with respect to the estimation period and the estimation method. Attention needs to be paid to this problem in further work on the dynamic properties and forecasting ability of the model.

The question of the effect of non-forestry income on the supply of wood is left open. In the reported results income changes obtained a negative and significant coefficient, the absolute value of which, nevertheless, has no meaningful economic interpretation. When income was measured using a level variable, a high level of income appeared to also signify a high supply of wood. It thus appears that, with the present aggregate data, it is not possible to bring out the effect of exogenous income, resulting from capital market imperfections, or there is no effect at all. The problem with the income variable is that it describes income developments of all households (and not nearly those that own forest land), and that the annual variation of the series in relation to the positive trend is very small (cf. Kuuluvainen (1986)).

The significant negative coefficients of the dummy variables connected with the post-energy-crisis recession and describing felling seasons 1975/76 and 1977/78 point to a much weaker-than-normal demand situation in those felling seasons. The positive dummy in the felling season 1978/79 in the saw log supply equation on the other hand indicates that supply strengthened towards the end of the 1970s, which could not be explained by the other variables included in the equation. Underlying this is apparently the conclusion of the first price agreement on saw logs and the discussion previsaging volume guidance and pricing systems in roundwood trade and the falling price expectations of roundwood sellers associated with these.

3.4. The pulpwood market

The statistical properties of the equation describing the pulpwood market of the model are weaker than those of the saw log model. An autocorrelation correction was needed in both equations. Positive autocorrelation refers to a certain »stickiness», in which case the model tries to produce consecutive explanatory errors in the same direction. In the demand equation, only the coefficients of the lagged endogenous variable and the dummy variables describing the recession are statistically significant, even though the signs of all coefficients corresponded to expectations. For example, demand appears to be fully inelastic with respect to the stumpage price, i.e.

price elasticity does not significantly differ from zero.

In the supply equation the price variables behave in the same fashion as with saw logs. Both the current period and the previous period price are significant and have the expected signs. The price elasticity of supply with respect to the present period stumpage price is approximately 0.6. In uniformity with the saw logs, the coefficient of the lagged price had a greater absolute value than the coefficient of the price of current period. When interpreting the absolute values, one should note however, that possible multicollinearity between the same period prices of saw logs and pulpwood may weaken the ability of the model to separate the effects of different price variables.

Measured as a relative change from the previous period, the income variable obtains a negative coefficient as expected, which, however, is not significant. On the basis of the cross elasticity estimate, the price of logs does not have any effect on the supply of pulpwood.

3.5. *Pulpwood from thinnings*

When saw logs are purchased or felled, a constant proportion of pulpwood also comes on to the market. This part of the total supply of pulpwood cannot be assumed to react to the price of pulpwood in the same way as the supply of pulpwood from thinnings. If we expect that industry buys and uses primarily the pulpwood that originates from sawtimber stands, the pulp and paper industry demands pulpwood-dominated stands as a »residual». The greater is the supply of pulpwood coming on to the market with saw logs, the less is industry willing to buy thinning stands. On the other hand, the more income forest owners obtain from sawtimber stands, the less willing will they be to sell thinning stands.

For these reasons the pulpwood model was alternatively estimated in such way that the variable to be explained was the computational quantity of pulpwood coming from thinnings. The quantity of pulpwood ck_t^* demanded/supplied from thinning stands was obtained with the aid of the average saw log share b of sawtimber stands as follows (for more details see Kuuluvainen et al. (1987)):

$$(6) \quad ck_t^* = ck_t - ck_t^a = ck_t - ((1-b)/b)\, cs_t$$

where ck_t is the entire quantity of pulpwood traded, ck_t^a is pulpwood coming from sawtimber stands and cs_t the volume of saw logs.

Table 3 presents the results of estimation experiments in which the quantities of pulpwood traded are measured with the volumes of pulpwood from thinnings calculated as described above. An autocorrelation correction was also necessary now. Instead, recession-describing dummy variables were not used.

The price elasticity of demand estimated here is greater than for the demand for all pulpwood in Table 2. Furthermore, the elasticity is statistically significant at a 10 per cent risk level. The elasticity of demand with respect to the export price is also higher but even now it is not statistically significant.

In the supply equation, the coefficients of all variables with the exception of exogenous income are significant and have the expected signs. The coefficients of both the current period and the expected (lagged) price are statistically highly significant. Supply is clearly more elastic (1.55) with respect to the prevailing price than in the results obtained for total pulpwood. In addition, the coefficient of the current-period price is now greater than that of the lagged price. Furthermore, the cross elasticity with respect to the price of saw logs now proves to be significant and negative. In other words, a higher price for saw logs appears in the short run to weaken the supply of pulpwood from thinnings.

4. *Conclusions*

On the basis of the estimation results, it is possible to describe the functioning of both the saw log and pulpwood markets using a simultaneous equilibrium model which conceptually corresponds to competitive, flexiprice markets which reach equilibrium. There are, however, no grounds for drawing very far-reaching conclusions. Although the markets appear to reach equilibrium at the national level for each felling season, this does not exclude the occurrence of disequilibria regionally or in short periods (slowness of adjustment). The actual testing of the equilibrium vs. disequilibrium hypothesis would, however, require in addition the estimation of a disequilibrium model (Brännlund (1988)).

Few differences emerge in the estimated results between the submarkets. This is surprising, when one takes into account the difference in the structure of the submarkets and in the coverage of the recommended stumpage price agreements discussed above. There were no clear signs that agreements lead to price rigidities. The explanation errors taken into account by the use of dummy variables could not, as regards timing or direction, be interpreted as the effects of price rigidity.[3] Either the actual differences between partial markets are not great or they cannot be identified with the technique used.

According to the results, both the demand for and supply of saw logs react to the stumpage price (Table 1). The export price of sawngoods strongly affects demand. The supply of logs is clearly less elastic with respect to the stumpage price of the current period than shown in earlier studies (Korpinen (1981); Kuuluvainen (1986); Tervo (1986); cf. also Brännlund et al. (1985)). The supply also depends on sellers' stumpage price expectations, which in this study were assumed to be formed according to the adaptive expectations hypothesis. Furthermore, the positive cross elasticity of the supply of saw logs with respect to the price of pulpwood shows that a higher price for pulpwood also stimulates the saw log trade.

The pulpwood trade also reacts to prices as expected, although the effects of prices on the demand for pulpwood were less clear than for saw logs. When the total quantities of pulpwood were used (Table 2), the stumpage price for pulpwood did not seem to influence the demand for it at all. The elasticity with respect to the price of products was of the order of one. By contrast, the price elasticity of supply was clearly significant, albeit with a low absolute value like saw logs. The price of saw logs did not have any effect on the total supply of pulpwood.

When the volume variable for pulpwood was wood originating from pulpwood-dominated stands (thinnings), the elasticity of demand with respect to the stumpage price proved significant (Table 3), but the effect of the export price was not significant. Estimated this way, the price elasticity of supply turned out to be clearly higher than for total pulpwood. In addition, the cross elasticity of supply with respect to the price of saw logs is clearly significant and negative. According to the result, a rise in the saw log price crowds out thinnings in the short run.

[3] *The price rigidity caused by a binding agreement would in theory always reduce the quantities traded compared to the equilibrium volumes (Fig. 1c). However, in studies on the supply of saw logs the price agreement dummy has obtained a positive sign (Kuuluvainen (1986)) and in Tervo (1986) the price agreement dummy was not significant, whereas the volume agreement appeared to augment the quantities traded.*

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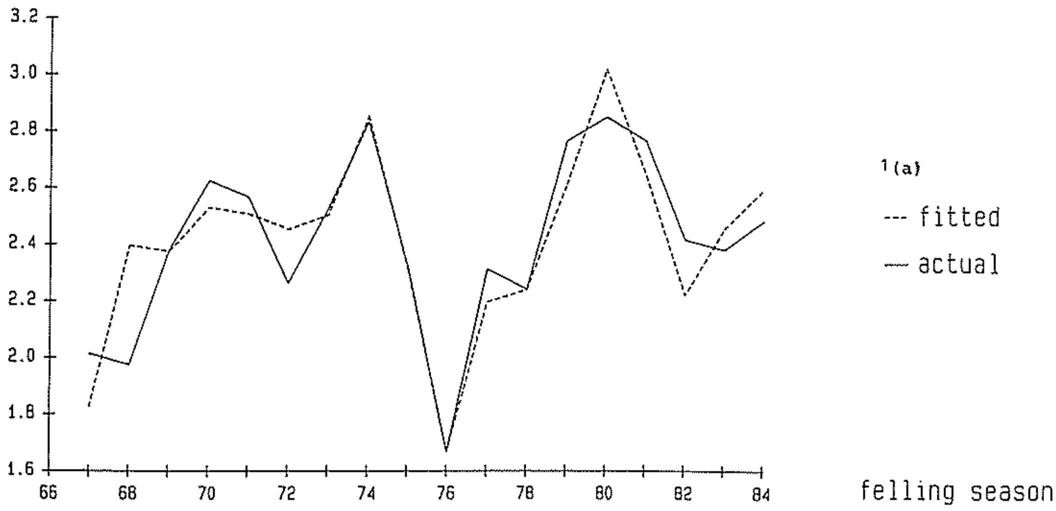
Appendix



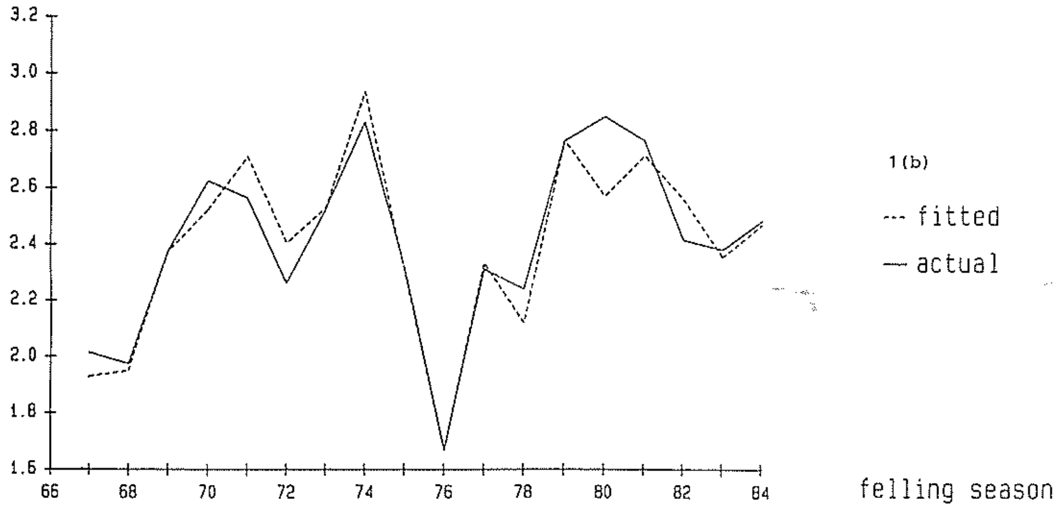


Figure 1. Actual and fitted values of sawtimber demand (a) and supply (b) equations, 1967—1984 (i.e. felling seasons 1966/67—1983/84).

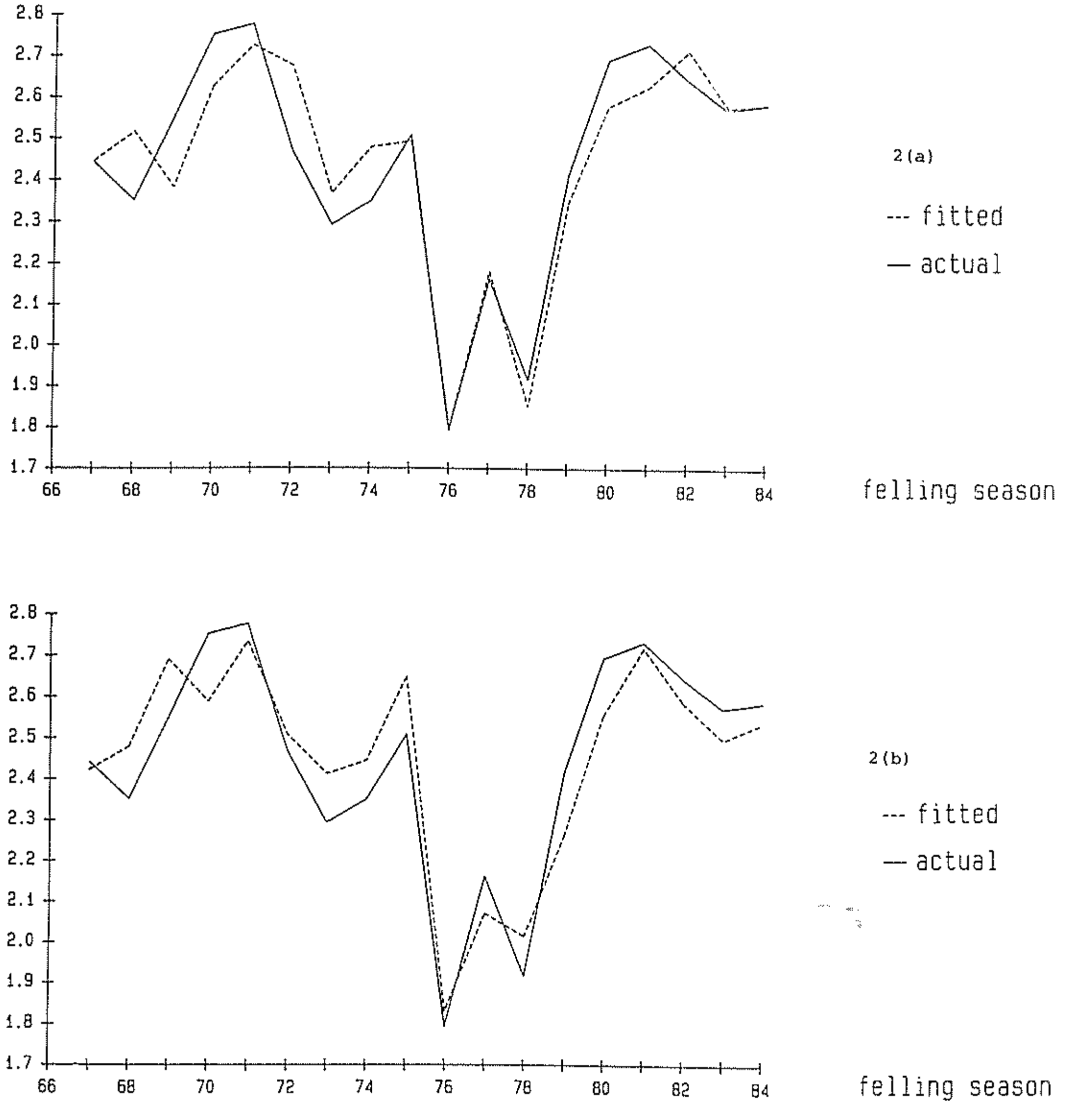


Figure 2. Actual and fitted values of pulpwood demand (a) and supply (b) equations, 1967—1984.

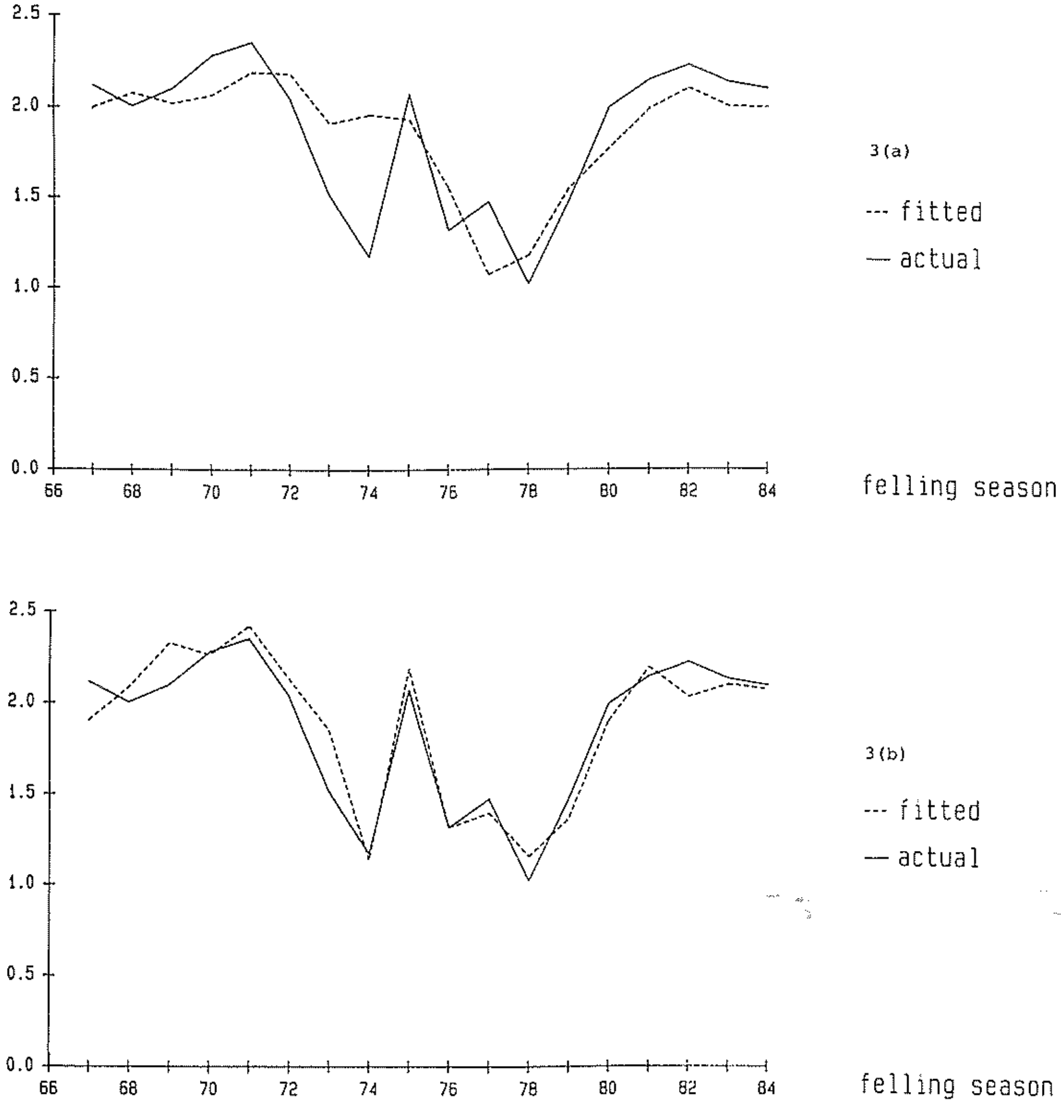


Figure 3. Actual and fitted values of pulpwood demand (a) and supply (b) from thinnings, 1967—1984.