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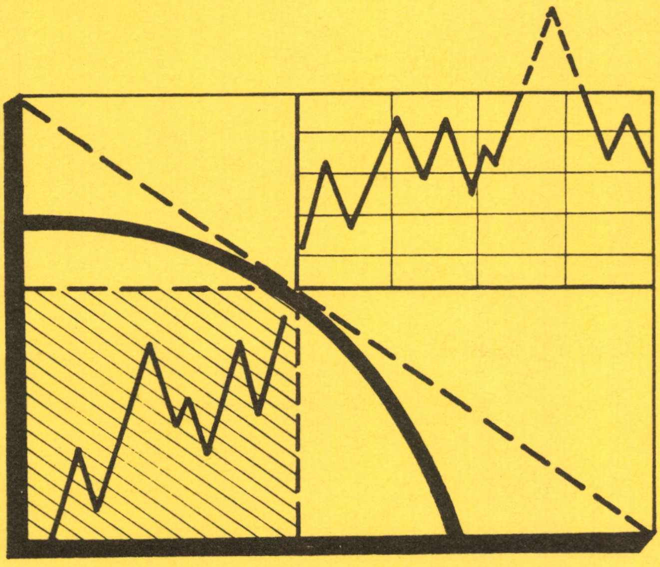
SHORT TERM DEMAND FOR AND SUPPLY OF SAWLOGS IN FINLAND

JARI KUULUVAINEN



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Sawnwood accounts for about ten per cent of the total value of Finnish exports (65 per cent of total sawnwood production is exported). Sawlog sales have been little less than 50 per cent of the private nonindustrial forest owners' stumpage income during the 1970's. Private forest owners supply 80 per cent of the total raw material input of forest industries.

The model of the representative firm is adapted from Mills (1962), who considered production and stock holding decisions of an imperfectly competitive firm under stochastic final good demand. The present study shows that ex ante raw material stock holding decisions determine the sawlog demand of the representative firm. In the model, uncertainty concerning sawnwood demand in export markets causes the optimal ex ante raw material stock to deviate from the level suggested by a simple accelerator of expected demand. For the expected profit maximizing firm the ex ante stock is an increasing function of expected sawnwood demand and price, expected stumpage price and initial stock (adjustment costs) and a decreasing function of present stumpage price and the carrying costs of stocks. In the presence of uncertainty and adjustment costs, the firm does not necessarily want, ex ante, to produce the expected mean demand.

For a one period utility maximizing forest owner, the supply of sawlogs is shown to be an increasing function of stumpage price and standing stock (standing timber inventory) and a decreasing function of exogenous income (Binkley, 1981). The intertemporal utility maximizing approach is discussed and the above one period model and the present value maximizer's model are concluded to be special cases of this more general approach. Ambiguity of the results of the intertemporal utility maximizing model leads to the selection of a one period model as the basis for empirical work. Further more, institutional factors and market imperfections do not support the present value maximizing approach in the present empirical context. The estimated supply equation is an application of Houthakker's and Taylor's (1970) stock adjustment model.

The estimated raw material stock adjustment equation and simultaneous sawlog market models support the implicit relationships derived in the theoretical part of the study. The demand for sawlogs is concluded to be inelastic with respect to stumpage price and elastic with respect to expected sawnwood export price. The supply of sawlogs is elastic with respect to stumpage price.

Actual sawlog sales (purchases) produce larger estimates for price elasticities in absolute terms than commercial fellings which are concluded not to be a very good market situation indicator in the short run.

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PREFACE

The present study of the short term demand and supply of sawlogs in Finland was initiated during my work in the project "The Finnish Forest Sector Planning Model". This project considered the long term development possibilities of the Finnish forest sector, and was led by Risto Seppälä. He encouraged me to carry out analysis on the forest sector's economic activity in the short term, which was out of the scope of that project but never-the-less an important and fairly little studied area in the Finnish forest economics tradition. To keep the problem field manageable the work concentrated on the sawlog market, which plays an important role in the Finnish roundwood markets.

I want to thank Lauri Heikinheimo, my department leader, for creating a good working environment and for support at all stages of the study.

Vesa Kanniainen, Heikki A. Loikkanen and Pekka Ollonqvist read the manuscript and provided comments and valuable suggestions concerning different parts of the report. Kari Djerf gave me useful advise during the empirical part of the study while Jorma Salo's help in handling the data and keeping my files in order was irreplaceable.

Jaakko Heinonen and Risto Häkkinen helped in constructing the sampling to obtain semiannual sawlog sales and price observations used in the study. Esko Korsulainen performed the laborous computations of the sampling. Jaakko Heinonen also guided me through some mathematical difficulties of the theory of the firm.

Particular thanks are also due to Eila Iltanen for gamefully and efficiently coping with the typing of the equations, to Maija Kuusijärvi for patiently drawing and redrawing part of the figures, and to Ashley Selby for checking the language.

To these and many other colleagues and friends I wish to express my sincere gratitude. Remaining errors are entirely my own responsibility.

Finally I want to thank OKO Bank's Kyösti Haataja Foundation for financial support at the preliminary stage of the study.

Jari Kuuluvainen

CONTENTS

LIST OF FREQUENTLY USED SYMBOLS (Chapters 4,5 and 6)

Lower case letters refer to the representative firm or forest owner, upper case letters to aggregated relationships unless indicated otherwise.

t	Time subscript (in order to avoid extensively long equations, subscribt +1 is used to denote t+1 in the model of the representative firm)
a	Parameter of the cumulative distribution function $F(v)$
B_i	Coefficients of the estimable supply equation of sawlogs ($i=1,..\ ,5$)
$\bar{c}$	Constant penalty of shortage
c_t	Consumption of goods and services of the representative private nonindustrial forest owner
d_{t+1}	Vector of shift variables in the deterministic part of the sawnwood demand function
E_{it}	Error term ($i=1,\ ,7$)
e	1) Expectations superscript 2) Base of the natural log
$F(v)$	Distribution function of the stochastic component in the sawnwood demand function
$f(v)$	Density function of the stochastic component of the sawnwood demand function
$h(y_{t+1},\bar{p}_{t+1})$	Mean of the unsatisfied demand in the expected revenue function
I_t	Marginal rate of interest on Central Bank debt
i	Time preference, private nonindustrial forest owner
K_t	Aggregate stocks of sawlogs <u>at the beginning of period t</u>
k_t	Stock of sawlogs <u>at the beginning of period t</u>, representative firm (note definitions of S_t and s_t below)
M_t	Aggregate exogenous income, private nonindustrial forest owners
ΔM_t	Exogenous income, first difference ($\Delta M_t=M_t-M_{t-1}$)
MH_t	Aggregate commercial fellings of softwood sawlogs
m_t	Exogenous income, private nonindustrial forest owner
n	Slope of the adjustment cost function (associated to changes in raw material stock of the representative firm)

$P^e_{t,t+1}$ Aggregate expected sawnwood export price

$\bar{P}_{t+1}$ Production period sawnwood export price

p_t Price of goods and services in the model of the private nonindustrial forest owner

pv_t Present value of stumpage income, private nonindustrial forest owner

Q_t Aggregate stumpage price of sawlogs

$Q^e_{t,t+1}$ Aggregate expected stumpage price

ΔQ_t Stumpage price of sawlogs, first difference ($\Delta Q_t = Q_t - Q_{t-1}$)

q_t Stumpage price of sawlogs

r_t Carrying costs of raw material stocks

$R^e_{t,t+1}$ Aggregate expected carrying cost of stocks

RQ_t Aggregate user cost of capital

S_t Aggregate stock of standing timber at the end of period t, private nonindustrial forest owners

s_t Stock of standing timber at the end of period t, representative private nonindustrial forest owner

T End of the private nonindustrial forest owner's planning horizon

U Forest owner's intertemporal utility function

u Forest owner's one period utility function

$\bar{U}_t$ Aggregated consumption of sawlogs in sawnwood production

$\bar{u}_t$ Consumption of sawlogs in sawnwood production

v Stochastic component of the additively stochastic sawnwood demand function

X^D_t Demand for sawlogs

X^S_t Supply of sawlogs from private nonindustrial forest

X^{TS}_t Total supply of sawlogs

X^{OS}_t Supply of sawlogs from other forest owner groups than private nonindustrial forests

x_t Sawlog sales or purchases, representative forest owner and representative firm respectively

Y_t Aggregate production of sawnwood

y_t Actual production of sawnwood during period t, representative firm

y^*_t Planned production of sawnwood during period t, representative firm

y_{t+1} Planned production of sawnwood during period t+1, representative firm

$z^e_{t,t+1}$ Aggregate expected demand for sawnwood

z_{t+1} Demand for sawnwood, representative firm

$\bar{z}_{t+1}$ Deterministic part of the sawnwood demand function

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α Coefficient of proportionality of the sawnwood production function

Γ_i Parameters of the aggregate structural sawlog supply equation, (i=0,1,.. ,3)

Δ Difference operator

δ Adjustment coefficient of the stock equation (both representative firm and aggregate model)

θ_i Structural parameters of the equation of aggregate beginning-of-production-period desired raw material stock, (i=0,.. ,5)

ξ Parameter in the linear approximation of f(v)

λ Uncertainty parameter in linear approximation of F(v)

μ Lagrange multiplier

Π_i Coefficients of the aggregate estimable sawlog demand equation (i=0,... ,7), (note, Π_7 is the coefficient of the sum of initial raw material stocks and consumption of raw material during period t)

ρ 1) Function giving the value of the end-of-production-period raw material stock or the cost of shortage, $\rho(1/\alpha)(y_{t+1}-z_{t+1})$

2) Parameter estimate of the coefficient of serial correlation

Φ_i Coefficients of the aggregated estimable stock equation (i=1,...5)

DEFINITIONS

Export price - the price that the firm or industry gets from sawnwood in export markets. In empirical analysis unit value of export shipments (Standard International Trade Classification, SITC 248, 2) is used as a proxy.

Contract price - the price of sawnwood agreed on when signing the sales contract.

Sawlog - piece of large sized softwood timber used as raw material by the sawmill industry.

Sawnwood - final good of sawmills and planing mills (STIC 248, 2)

Stock of standing timber - growing trees in the forest of private nonindustrial forest owner (in the literature often refered to as standing timber inventory). Because the present work is only concerned with the supply and demand of sawlogs, the term often refers only to the part of the stock consisting of sawtimber trees.

Stock of sawlogs (also referred to as stock of raw material when there is no danger to confusion) - aggregate sawlogs stocks of sawmill industry (or firm), consisting of purchased growing and felled sawtimber trees and stocks of sawlogs alongside roads and at factories.

Timber (or roundwood) - includes both large sized timber and pulpwood (note the definition of the stock of standing timber, above).

1. INTRODUCTION

1.1. The problem area

The present study is concerned with the trade of softwood sawlogs in the Finnish roundwood markets. Sawlogs are used as raw material of the sawmill industry. The proportion of the gross value of production of manufacturing industries accounted for by sawmills and planing mills has been decreasing during the past two decades, and was in 1983 a little less than 5 per cent. Its share of the value added was slightly more. During 1970's about 65 per cent of the total production of sawnwood was exported, and the export trade has clearly dominated the production decisions and price development in this branch of industry. Sawnwood has accounted for 10 per cent of the value of total Finnish exports in the 1970's and slightly more in the 1960's.

Because sawlogs form the most valuable part of the roundwood, their stumpage price development is an important determinant of roundwood supply decisions. The sawlog stumpage price is about twice the price of pulpwood. For example during 1970-1974 the share of stumpage incomes coming from sawlogs was about 50 per cent of the total stumpage income of the private nonindustrial forest owners. The private nonindustrial forest owners are the major suppliers of raw material to the sawmill industry. Commercial fellings from private nonindustrial forests were about 85 per cent of the total fellings in 1971-1975. Their share has also been increasing, being only 62 per cent in 1955-1959 (Tervo, 1978 p. 31).

Present study investigates the factors affecting the demand for and supply of sawlogs. Empirically interesting features in the sawlog market, which so far have not gained enough attention are the influence of the stock holding decisions of the sawmill industry and the development of the amount of sawlogs actually traded (compared to the development of commercial fellings). Because the share of stumpage sales, and therefore the share of standing roundwood stocks held by the industry, has been increasing since the mid-1960's, commercial fellings can no longer be considered a good indicator of the amount of roundwood actually traded in the short run. Standing stocks account for approximately 50 per cent of the total sawlog stocks of sawmill industry. The forest industry firm can cut the wood it has purchased on the stump up to two years from signing the contract. Therefore both timing and relative fluctuations of the quantities actually traded and commercial fellings can differ.

1.2. The purpose of the study

The present study analyses the behaviour of the sawmilling industry firms and private nonindustrial forest owners in the sawlog market in Finland. The study concerns the short run market behaviour.

Empirical econometric investigations of the Finnish roundwood markets usually give only implicit indications of the micro economic structure behind the estimated model. The present investigation will concentrate initially on the behaviour of the agents in the sawlog market at the micro level. Implicit sawlog demand and supply functions for the representative sawmill industry firm and for the representative private nonindustrial forest owner will be derived.

The role of the raw material stocks are given special emphasis. Thus, an attempt will be made to demonstrate the implications of different motives for holding stocks on the behaviour of the representative firm. It will be argued that for the representative firm the reason for holding raw material stocks above the technically required minimum is to buffer uncertain final good demand and to anticipate price changes. In the empirical part of the work only export markets are considered. The reason for this is inadequate data from domestic markets and the still dominant role of the export trade in production decisions.

The short run sawlog supply will be considered from the point of view of the present value maximizer of stumpage income and of the utility maximizing forest owner. When the private nonindustrial forest owners are assumed to be utility maximizers, their utility function has two arguments: i) consumption of goods and services and ii) the standing stock of their woodlots. Sawlog supply is obtained from the solutions of the maximizing problems. Although the microfoundations of sawlog demand and supply are discussed in detail, the choice of the empirical estimable functions remains to a certain extend a subjective matter. The theoretical models of the representative firm and forest owner only give implicit demand and supply relationships. Linear approximations are used in estimations.

The paper proceeds as follows. After a review of literature in chapter 2, the assumptions of the sawnwood and sawlog markets are discussed in chapter 3. Reference is made to the empirical evidence concerning the different nature of these two markets. Motives for carrying stocks are also discussed. In chapters 4 and 5 sawlog demand and supply functions are derived. The data and the results of the estimations are presented in chapter 6, followed by summary and discussion in chapter 7.

2. SELECTED LITERATURE

The literature relevant to the present study is divided into three main groups: i) empirical market models dealing with the stumpage and/or final goods markets, ii) the timber supply models from the point of view of the private nonindustrial forest owner and iii) the studies of the behaviour of the firm with special emphasis on the production and stock holding decisions.

In the United States there exists an extensive tradition of empirical econometric work on the stumpage and final goods markets.[1)] In Finland Korpinen (1981) has estimated a model for the sawlog market using annual data. The roundwood supply behaviour of different forest owner groups has been studied by Tervo (1978; 1981). Brännlund et al (1983) estimated an econometric model for roundwood supply in Sweden. For sawlogs they estimated both supply and demand equations, but because the pulpwood price was considered exogenous to the market system only the pulpwood supply equation was estimated.

The problem with econometric stumpage market models has often been that their supply and demand specifications are ad hoc. They therefore give only implicit information concerning how the roundwood supply and demand decisions are made. These econometric models mainly aim at forecasting the future development either in the short term (cf. Gregory, 1960; McKillop, 1969; Adams and Blackwell, 1973; Leuschner, 1973; Adams, 1974; Robinson, 1974) or in the medium or long term (cf. Adams, 1975 and 1977; Haynes and Adams, 1980). A policy analysis is also often emphasized, specially in the long term models (cf. Adams, 1977; Adams and Haynes, 1980), which are used to simulate the possible future developments under different assumptions.

Binkley (1981) and Knapp (1981) model the roundwood supply behaviour from a microeconomic point of view. They formulate models of a representative forest owner explicitly and derive supply functions. Binkley (op cit) stresses the imputed utility of the forest property when the amenities do not have markets but enter directly to the utility function of the forest owner together with the consumption of goods and services. In Knapp's work (op cit), on the other hand, the main emphasis is on the long run steady state roundwood supply given perfect markets for both amenities and roundwood.[2)] Knapp also derives a roundwood supply function for the short term (disequilibrium supply), and shows the dependence of the supply on prices, price expectations and the beginning-of-period stock of standing timber (op cit, p. 98). Both Binkley and Knapp use their theoretical framework as a basis of empirical estimations of roundwood supply.

The model of the representative sawmill industry firm in the present study concentrates on raw material demand, stock holding and production decisions assuming that firms do not own forest land. This is justified because in Finland less than 10 per cent of the raw material input of the forest industry comes from its own forests (Tervo, 1978 p. 21).

The literature on the empirical stock models builds mainly on the work by Holt et al (1960) on the optimal production and inventory investment policy. Empirical stock models are often applications of the flexible accelerator model initiated by Lovell (1961). The linear dependence between the expected sales and optimal level of stocks of final goods is most often assumed in order to obtain estimable equations. Recently the role of the capital costs, prices and price expectations (inflation expectations) in stock management decisions have also been studied (cf. Maccini, 1977; 1978; Maccini and Rossana, 1981; Irvine, Jr, 1981a and 1981b). These studies claim that the adjustment of expectations is sluggish, but that the stock adjustment, as such, is rapid. This contradicts the earlier empirical results of very slow adjustment to target stock levels (cf. Lovell, 1961).

Feldstein and Auerbach (1976) stress the rapid adjustment of actual stocks to target level by claiming that it is the target adjustment which takes time. In many cases the argument is tenable when realizing that even major changes in, e.g., the final goods stocks, do not require more than a fraction of a month's production. Feldstein and Auerbach report empirical results supporting their target adjustment argument (op cit).

Both theoretical and empirical studies are mainly concerned with stocks of final goods. This holds also for more macroeconomically orientated theoretical works of Blinder (1978; 1980; 1981a; 1981b and 1982) and Maccini (1976). While for example, Lovell (op cit) and Feldstein and Auerbach (op cit), also report empirical results concerning raw material stocks, the theoretical structure behind the estimated equations is given less attention than in the case of stocks of final goods.

Mills (1962) constructed a model for a representative firm to study the price, production and final goods inventory decisions. The study shows the interaction between price and production decisions and the optimal ex ante level of final goods stocks. He further shows that for an imperfectly competitive firm the optimal production level, also determining the optimal ex ante end of period stock, depends on the trade-off between shortage costs and the carrying costs of stocks. For the firm facing stochastic demand, the motive for holding stocks is best described by the buffer-stock motive. Atkinson (1981), using Mills' approach, showed that most empirical flexible accelerator models for final goods oversimplify, by assuming a constant positive accelerator. Theoretically, the accelerator is not constant and need not even be positive. Never-the-less, Atkinson gives the assumptions needed for a positive constant accelerator. The present investigation will utilize Mills' approach to the raw material demand and stockholding decisions of the representative sawmill firm. However, it will be demonstrated that the motive for holding raw material stocks in the present case is not only to buffer uncertain demand, but also to anticipate prices.

Before considering the derivation of demand and supply functions, some basic assumptions that will be made concerning the sawlog and sawnwood markets are discussed.

Notes on chapter 2:

1) A review of econometric stumpage market studies is given by Adams and Haynes (1980). They categorize these studies into "gap", nonspatial market, quasi-spatial market and spatial market models. This categorization is based on whether or not the model provides estimates of equilibrium prices and quantities ("gap" versus market models) and to what extent the spatial aspects of forest product markets are taken into account. In the Finnish roundwood markets the behaviour of different forest owner groups is probably more interesting than the spatial aspects (cf. Tervo, 1981).

2) Knapp shows that the perfect market assumption of amenities can be relaxed without affecting land allocation, if the land markets are perfect.

3. SAWLOG AND SAWNWOOD MARKETS

3.1. Flexprice or fixprice model

Stocks are an important feature of the roundwood markets. The supply of roundwood in the short run is actually stock supply and the stocks of raw material of the sawmill industry (including the stocks of standing sawtimber trees and the stocks alongside roads and at factories) cover, on average, the raw material input of more than half-a-year's production. Two novelties of the sawlog market are the total lack of substitutes for sawlogs in sawnwood production, and the fact that for the forest owner timber production creates few variable production costs in the short run. Therefore, whereas the seller is free to choose the time and quantity of sales, the producers of sawnwood are, in the short run, dependent on the availability of raw material. For the forest owner, postponing sales causes little more than the opportunity cost of sales income. This is likely to affect the market behaviour of the sellers and buyers and therefore price formation and the raw material stock management decisions of the firms.

Because of the lack of substitutes, the stumpage price has sometimes been excluded from the short run roundwood demand function entirely (Adams, 1975 p. 305, Leuschner 1973, p. 42). This would indicate wide price and quantity fluctuations in response to shifts in demand curve, but shifts in supply would only result in price changes. The present work argues that when the final good demand is stochastic and the raw material can be stored, stumpage prices in fact affect the input demand in the short run even if the firm's production function is directly proportional. This is because all raw material goes to production via stocks. Low stumpage prices (or their expected increase) make it profitable to have bigger stocks, other things being constant whereas high stumpage prices make it profitable to carry smaller stocks.

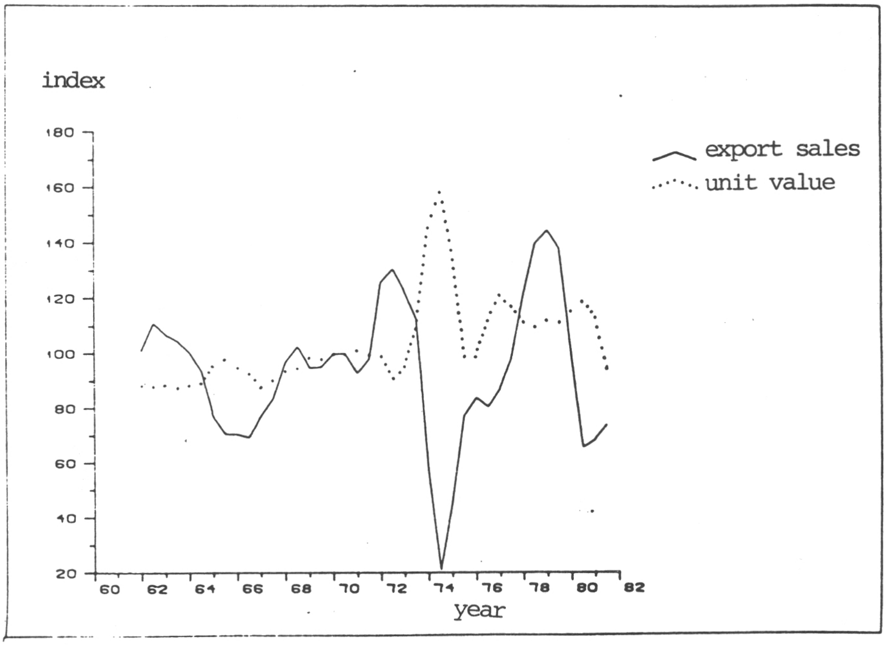


Figure 1. Export sales of sawnwood (semiannual three term moving averages) and the unit value of export shipments (semiannual observations deflated using whole sale price index), 1960/2 - 1982/1. Both series are given as indices (1970/2=100).

The carry-forward of stocks makes price rigidities possible. If the demand exceeds supply during the ongoing period, prices can more easily remain constant if there are stocks from which the excess demand can be satisfied. This means that price changes are replaced, at least in part, with changes in the level of stocks (Hicks, 1965 chapters V-VII). A fixprice assumption means that the prices are exogenous and are not determined inside the model (op cit, 1965 pp. 78-79).

The sawnwood export markets of the Finnish forest industries are characterized by relatively large cyclical variations in quantities but fairly even price development (Figure 1). It seems likely, therefore, that in the export sawnwood markets there are elements which are able to partly replace prices in balancing the demand and supply. For example, the stocks of sawnwood held by the importers and the dominance of production to order are likely to cause price rigidities.

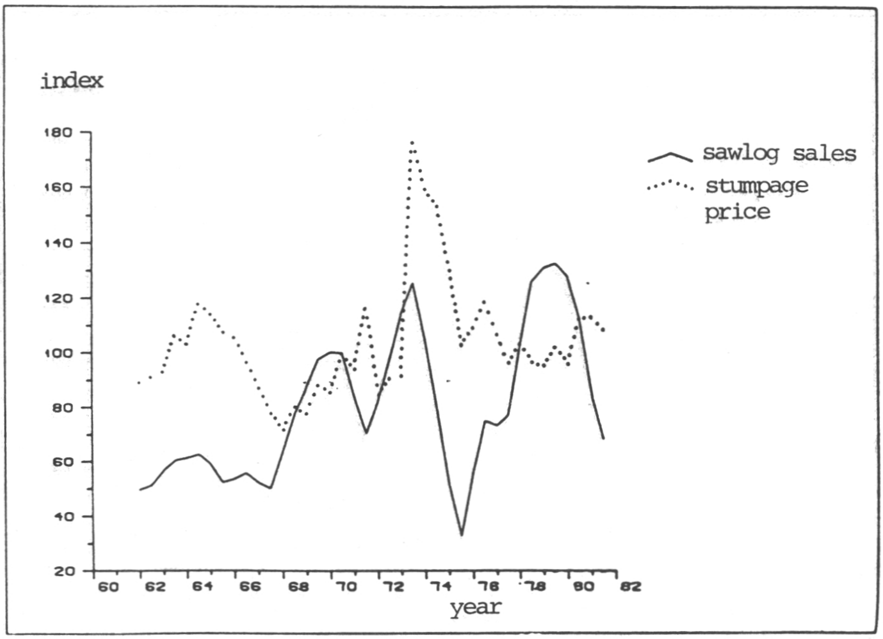


Figure 2. Sawlog sales from private nonindustrial forests (semiannual three term moving averages) and saw-log stumpage prices (semiannual observations deflated using whole sale price index), 1960/1-1981/1. Both series are given as indices (1970/2=100).

The development in the sawlog market is different (Figure 2). Both quantities and stumpage prices experience strong cyclical variations. In spite of the extensive carry-forward of stocks, prices are flexible and reflect the changes in present and expected supply-demand situation in the markets.

Samuelson (1965) has shown that properly anticipated prices fluctuate randomly (see also Korhonen, 1977). Using autocorrelation and partial autocorrelation functions of sawlog and sawnwood prices it is possible to actually observe a different type of price adjustment in these two markets.

Autocorrelation and partial autocorrelation functions of the deflated and nominal prices are presented in appendix 2, p. 118. According to these functions, the stumpage price adjustment is much faster than sawnwood prices. Nominal stumpage prices, in particular, seem to be close to a random walk (cf. Granger & Newbold, 1977 p. 38). The autocorrelation of levels decays rapidly and the partial autocorrelation function has a cut off at the first lag. Autocorrelation and partial autocorrelation functions of first differences of the nominal stumpage prices both have only one almost significant peak with no economic interpretation.

It is considered to be out of the scope of the present study to go into a detailed examination of the four price series. Therefore it is only pointed out that contrary to the stumpage prices, the export unit values of sawnwood according the autocorrelation and partial autocorrelation functions are clearly serially correlated. This indicates an autoregressive or some mixed process in price adjustment. Therefore the behaviour in the sawlog market may be viewed as resulting from asset motive (stocks are used to anticipate prices) so that prices tend to be fairly flexible (and also sensitive to expectations). On the contrary, in sawnwood export markets prices tend to be rigid being very much affected by the current flow demand and flow supply so that stocks are buffer stocks (see Kanniainen and Kuuluvainen, 1984 for the discussion of price formation in these two markets).

3.2. Motives for holding stocks

For a competitive firm in price flexible markets, the motive for holding stocks is often argued to be speculative. Because the firm can sell at the current price any amount it chooses, the reason for holding stocks is to be able to sell them at the most profitable point in time. The firm can of course also speculate with the raw material prices, especially if the raw material costs are relatively large compared to other variable production costs (for a discussion on the stock holding motives, see Blinder, 1980).

The situation is different if prices, for one reason or another, are rigid, in which case the ruling price is not necessarily the equilibrium price. Then the firm may not be able to sell its production even at the going price. Arrow (1959) has shown that in disequilibrium, firms behave like monopolists, even in objectively competitive markets. In imperfectly competitive markets, information is not totally carried by the prices and the firms are tracing their demand curves by trial and error.

If the firm does not know exactly how much will be demanded per period at the ruling price, the firm is likely to produce an amount that permits a remaining stock at the end of the period (Mills, 1962 p. 82). The firm can obtain zero stocks only by producing so little that, on average, some profitable sales are missed. On the other hand, if potential no sales are missed, stocks are likely to be unprofitably large. This is the buffer stock motive, where the problem is how much risk is worth taking by carrying different amounts of stocks. The optimal stock is determined by carrying costs, final product prices and production costs, probability distribution of demand and the length of the firms planning horizon.

Mills (op cit) considered the case where the firm could actually decide both the prices and the amount it produced. The situation is essentially the same even if the price is out of the firms control but the amount demanded at each price is uncertain (Atkinson, 1981).

The present study assumes that the motive of the representative firm to hold raw material stocks is partly a buffer stock motive in face of uncertain demand for sawnwood and partly a speculative motive in order to anticipate both raw material and sawnwood price changes. This is justified as follows. First, it is assumed that the sawlog market are characterized by flexible prices so that the demand and supply are equal in each period. Therefore the motive for holding raw material stocks in the roundwood markets is a speculative one. (The price elasticity of stocks, or their change with respect to stumpage prices, should be nonzero.) Of course, a certain minimum stock must be carried in order to cover the technical delays and to guarantee continuous production.

Sawnwood export markets are characterized by rigid prices resulting in uncertainty concerning the quantity demanded at each price. Abstracting from the final goods stocks and assuming that only raw material is stored, the motive for holding raw material stocks is the buffer stock motive in the face of uncertain final good demand. A strong buffer stock motive probably makes stocks less elastic to raw material price changes.

4. DEMAND FOR SAWLOGS

4.1. The model of the representative firm

4.1.1. Stochastic sawnwood demand and sales revenue

The production function of the representative firm is assumed to be directly proportional. The firm is using one storable input, which is sawlogs. Capital and other inputs are assumed to place no restrictions on production. All raw material goes to production through stocks. The stocks have to be bought before the production and the stocks of final goods are abstracted away. Therefore amount of sawnwood sold is that produced during the period.

The representative one period expected profit maximizing firm is a price taker in the sawnwood markets. It makes no decision concerning the price but uses the expected price level when deciding the ex ante optimal production level for the production period. Prices are assumed to be rigid (cf. Bruno, 1978 pp. 196-197). When prices are not fully flexible the amount demanded at each price during the production period is not known with certainty (cf. Atkinson, 1981 p. 314). The uncertainty about the demand facing the firm (given prices) may therefore be due to fluctuating aggregate demand, assuming stable market shares. All firms are equally affected when the aggregate demand changes. The price level, however, adjusts to the changed market situation slower than the quantities traded. The reasons for rigid price adjustment have been discussed in section 3.1. above.[1)]

The following additively stochastic demand function has been earlier used in the inventory models, for example, by Karlin and Carr (1958; 1962), Mills (1962) and Atkinson (1981),

(4.1) $$z_{+1} = \bar{z}(\bar{p}_{+1},d_{+1}) + v = \bar{z}_{+1} + v.$$

Here, $\bar{p}_{t+1}$ is the given final product price which the firm uses when it decides the optimal ex ante production level. The other known demand determinants are denoted by d_{t+1}, so that $\bar{z}_{t+1}$ is the deterministic part of the period's t+1 demand[2)]. The stochastic component of the demand, v, is independent of the price $\bar{p}_{t+1}$, which means that the firm makes equally good sales forecasts with all prices. The production period (shipments period) is denoted by t+1 and t refers to the present period, when the ex ante decisions are made. To avoid extensively long equations subscript t+1 is denoted by +1, when there is no danger of confusion. It is to be recalled from chapter 2. that the present model of representative firm is adapted from the approach used by Mills (see Mills, 1962). He, however, explicitly considered only the production period and final good stocks.

Explicit consideration of only one period would have been possible also here. In that case, the ex ante optimal production is decided at the beginning of the period and the raw material purchased simultaneously (before observing the numerical value of v). The periodization (explicit consideration of planning and production periods) is considered to describe the actual decision environment better. It also relates the theoretical model more closely to empirical analysis of the study and to the actual data used in estimations than the alternative one period model. The cost is heavier notation in deriving the optimal ex ante stock and demand for raw material.

The firm predicts z_{t+1} before observing the numerical value of v, the stochastic component of the demand, and makes the coming period ex ante production decision according to this prediction. When the production function is directly proportional so that substitution is not possible, the ex ante production decision also uniquely determines the raw material required for production.

Following Mills (1962), it is assumed that the firm knows the probability distribution of demand at the price $\overline{p}_{t+1}$ (and that the probability distribution is independent of time). Given the above additively stochastic demand function, when the probability density function of f(v) for any given price $\overline{p}_{t+1}$ is known, the cumulative distribution function F(v) can be calculated (Mills, 1962 p. 84)

$$(4.2) \qquad F(a) = \int_{-\infty}^{a} f(v)\,dv.$$

This gives the probability that v, the stochastic component of demand, is not going to exceed some limit, a. To guarantee non-negativity of the observed demand, it is assumed that E(v)=0 and that f(v) is defined over a closed interval $-\overline{z}_{t+1}(\overline{p}_{t+1}, d_{t+1}) \leq v \leq \infty$ (Atkinson, 1981 p. 314).

The firm simultaneously commits itself to a certain price and quantity produced (even if it does not actively decide on price). In some markets it is of course possible to wait until demand has materialized before deciding upon production or price or both. If the firm first observes the stochastic component of demand, and then makes decisions concerning price and production there is no uncertainty.

Even if the firm commits itself only to one of the above decisions, the analysis is not essentially affected by the uncertainty. For example, assume that the firm decides on production knowing only the probability distribution of demand, and sets the price only after realizing the value of v. In this case, the amount produced and the price are the same as in the riskless case when the demand function of the model is interpreted as the expected value of demand and the stochastic component v is integrated out at each price.

The uncertainty plays no role, because expected profits depend only on expected price, which can be interpreted as the stochastic mean of the price or as subjectively certain prediction. A similar argument holds if price is decided first and the amount produced is decided only after observing the value of the stochastic component of demand (Mills, 1962 p. 85).

Explicit consideration of uncertainty leads to a considerable complication of the model. In the present case, however, the model becomes more realistic and as will be seen shortly, uncertainty is found to play essential role in the raw material demand decisions. Without uncertainty, the raw material demand would be a directly proportional function of the subjectively certain prediction of demand, unaffected by price and cost variables. This is because the firm is a price taker in the sawnwood markets, the production function is directly proportional and the raw material price is unaffected by the amount of raw material purchased. Of course, the final good price must always cover the variable production costs otherwise nothing will be produced.

The total revenue from sales is defined as a minimum of price times quantity demanded and produced (cf. Karlin and Carr in Arrow et al., 1962 p. 161; Mills, 1962 p. 88).

$$(4.3) \quad tr_{sales} = \begin{cases} \bar{p}_{+1} z_{+1} & \text{when } z_{+1} \le y_{+1} = \alpha k_{+1} \\ \bar{p}_{+1} y_{+1} = \bar{p}_{+1} \alpha k_{+1} & \text{when } z_{+1} > y_{+1} = \alpha k_{+1}. \end{cases}$$

The firm does not carry final goods stocks. The total revenue formulation in (4.3) is, however, meaningful because raw material stocks dictate the maximum possible production during the period t+1. When demand (z_{t+1}) exceeds production (the stock multiplied by the coefficient of proportionality from the production function) the amount produced is sold. The raw material is simply left in stock, if the demand is less than possible production given the beginning-of-production-period raw material stock. Later, the assumption that the raw material consumption cannot cannot exceed the amount in the stock at the beginning of the production period will be relaxed in order to make the model more realistic. In (4.3) k_{t+1} is the stock above the technically required minimum (cf. Blinder, 1982 p. 336). The determination of the technically required minimum stock is not considered. The directly proportional production function is

$$(4.4) \qquad y = \alpha\bar{u},$$

where $\bar{u}$ is the amount of raw material required to produce the quantity y of sawnwood. The expected revenue arises, not from demand, but from expected sales. If the demand is greater than the amount produced, the total revenue is price times the amount produced. Therefore the total revenue does not depend only on the expected demand, but also on all moments of the probability distribution of f(v) (Mills, 1962 p. 88). The total revenue from (4.3) is price times demand ($\bar{p}_{t+1}z_{t+1}$) if production is greater than the amount demanded, otherwise the total revenue is price times production ($\bar{p}_{t+1}y_{t+1}$). Therefore expected revenue is not the price times expected demand, but price times expected sales. Expected sales depend on the mean demand ($\bar{z}_{t+1}$) truncated the point where $v=y_{t+1}-\bar{z}_{t+1}$, because $v-(y_{t+1}-\bar{z}_{t+1})$ is the shortage, when it is positive. Using (4.1), (4.2) and (4.3) the expected total revenue from sales can be written

$$(4.5) \quad E(tr)_{sales} = \int_{-\infty}^{y_{+1}-\bar{z}_{+1}} \bar{p}_{+1}(\bar{z}_{+1}+v)f(v)dv + \int_{y_{+1}-\bar{z}_{+1}}^{\infty} \bar{p}_{+1}y_{+1}f(v)dv,$$

which is equivalent to

$$(4.6) \quad E(tr)_{sales} = \bar{p}_{+1}\bar{z}_{+1}F(y_{+1}-\bar{z}_{+1}) + \bar{p}_{+1}\int_{-\infty}^{y_{+1}-\bar{z}_{+1}} vf(v)dv + \bar{p}_{+1}y_{+1}\left[1-F(y_{+1}-\bar{z}_{+1})\right].$$

This shows that the expected total revenue is a probabilitity weighted average of price times mean demand (the first term on the right hand side) and of price times production (last term on the right hand side) corrected with the integral in the middle to take into account the form of the density function of the stochastic component of the demand. Equation (4.6) is written in a more convenient form as follows,

$$(4.7) \qquad E(tr)_{sales} = \bar{p}_{+1}\bar{z}_{+1}(\bar{p}_{+1}, d_{+1}) - \bar{p}_{+1}h(\bar{p}_{+1}, y_{+1}).$$

This equation will be used later when deriving the marginal revenue from sales. The equivalence of (4.6) and (4.7) is shown in note 3 to this chapter. Equation (4.7) says that the expected revenue from sales is price multiplied by the mean amount of expected demand (deterministic demand) minus price multiplied by the mean amount of unsatisfied demand $h(\bar{p}_{t+1}, y_{t+1})$, which depends on the ruling price and the quantity produced (Atkinson, 1981 p. 315). When written out, mean unsatisfied demand is

$$(4.8) \qquad h(y_{+1}, \bar{p}_{+1}) = \int_{y_{+1}-\bar{z}_{+1}}^{\infty} (v - y_{+1} + \bar{z}_{+1}) f(v)\, dv.$$

Unsatisfied demand is always nonnegative. Mathematically, this is clear from (4.8). According to (4.7) the economic interpretation is as follows: If y_{t+1} and $\bar{p}_{t+1}$ are large enough to make excess demand over production impossible, no sales would be missed what ever the actual demand. In this case the total revenue would simply be price times mean total demand. Under normal conditions all possible demands cannot be met. (If the firm attempted this stocks would continuously be unprofitably large.) Therefore $h(\bar{p}_{t+1}, y_{t+1})$ is always a positive quantity (Mills, 1962 p. 88). Before deriving the marginal revenue function, the one period assumption is relaxed in the following section.

4.1.2. Multiperiod planning horizon and the terminal raw material stock

It was assumed above that the firm is able to produce only the amount dictated by the beginning of the production period raw material stock. In the following discussion, this assumption is relaxed by introducing a function which enables us to handle the firms multiperiod planning problem by considering only the first period.

Arrow (1957) has shown that it is possible to solve a multistage programming problem only by considering the first period, i.e. the procedure where only the first period is considered is not formally different from solving the multistage problem itself. The effects of the first period activities on a more distant future are represented as a function of present period events and states of nature.

Because all future decisions are made later in time than the first period and since the causation cannot travel backwards in time, future periods cannot affect the present one but of course the future expectations do affect present decisions. Therefore, for example, the expected value of the profits of the planning horizon is the expected value of the present period's profits plus a function representing the effect of the first period events on the expected profits in later periods. There exists a function of first period events that collapses the multistage problem into a single period problem (Arrow, 1957 p. 769).

Following Mills (1962, p. 118), the effect of the decisions concerning production period t+1 on expected future profits is presented as a function of the terminal raw material stock. The terminal stock is positive when the beginning of the production period stock exceeds the raw material required to produce the amount demanded ($k_{t+1} > z_{t+1}/\alpha$). The shortage, "negative stock", occurs when ($k_{t+1} < z_{t+1}/\alpha$), i.e. when demand is greater than possible production. Positive stocks impute positive value on expected profits, whereas shortage means costs. This is described by function $\rho(1/\alpha(y_{t+1}-z_{t+1})$.

Now the firm's optimum production period policy can be approximated by considering explicitely only the ex ante decisions concerning the production period. The function ρ has the sign of $(y_{t+1}-z_{t+1})$ because positive stocks impute a positive value on expected profits whereas shortage gives a negative value. This formulation makes it possible to relax the assumption that the only available raw material is that in the stock at the beginning of the production period t+1. Shortages can be met, but at cost. Costs are caused by the "emergency procurement" by which the raw material must be obtained, or they are simply the premium for risk that the firm considers justified when making the ex ante plans.

The total expected revenue from sales can now be written in the following general form

$$(4.9) \qquad E(tr)_{sales} = \bar{p}_{+1}\bar{z}_{+1} - \bar{p}_{+1}\, h(p_{+1}, y_{+1}) + \int_{-\infty}^{\infty} \rho \left[(1/\alpha)(y_{+1}-\bar{z}_{+1}-v)\right] f(v)\,dv.$$

Equation (4.9) is the same as equation (4.7) except for the last term, which gives the value of the terminal raw material stock, or shortage, at the end of the production period t+1. According to the last term, if $k_{t+1} > (z_{t+1}/\alpha)$ then a positive value is added to expected revenue, while $k_{t+1} < (z_{t+1}/\alpha)$ means a reduction in the expected revenue caused by the shortage. Marginal revenue from (4.9) is[4)]

$$(4.10) \quad E(mr)_{sales} = \bar{p}_{+1}\left[1-F(y_{+1}-\bar{z}_{+1})\right] + \int_{-\infty}^{\infty} \rho'(1/\alpha)(y_{+1}-\bar{z}_{+1}-v)\ f(v)dv.$$

The first term on the right hand side gives the marginal revenue from sales, which in effect is the price times the probability of being able to sell one more unit (Atkinson, 1981 p. 315). The second term is the marginal value of the stock or the cost of shortage. The expected marginal revenue is a decreasing function of the planned production. The derivate of ρ with respect to y_{t+1}, $\rho'=\partial/\partial y_{+1}(\rho(1/\alpha)(y_{t+1}-z_{t+1}))$ is not necessarily defined at the point where $y_{t+1}=\alpha k_{t+1}=z_{t+1}$. Therefore it must be formulated using two functions representing the value of stock and the cost of shortage, truncated at the point where production and sales are equal (Mills, 1962 p. 115).

4.1.3. Value of the terminal stock and the penalty of shortage

The value of the terminal stock at the end of the production period cannot be less than the price that the firm would have to pay to obtain an equal amount of the raw material at that time minus the carrying cost of the stock. It is assumed that the production continues, or if it does not, that the firm is able to sell the stock at the current price. Because the stumpage price is not necessarily the same at the end of the period t and t+1 the firm takes this into account.

The function ρ is represented by writing separately the value of stock and the penalty of shortage. As stated above function ρ normally takes the sign of $(y_{t+1}-z_{t+1})=(\alpha k_{t+1}-z_{t+1})$. Following explicit formulation for this function will be used

$$(4.11) \quad \rho\left[(1/\alpha)(y_{+1}-z_{+1})\right] = \begin{cases}(q_{+1}-r_{+1})(y_{+1}-z_{+1})/\alpha & \text{when} \quad y_{+1}\geq z_{+1}\\ (\bar{c}-(q_t-q_{+1}))(y_{+1}-z_{+1})/\alpha & \text{when} \quad y_{+1}<z_{+1},\end{cases}$$

where q_{+1} - stumpage price of period t+1

r_{+1} - carrying cost of stock (including rate of return from alternative investment)

$\bar{c}$ - penalty of raw material bought during the period t+1, or the cost of shortage (including rate of return from alternative investment).

The value of the terminal raw material stock at the end of the production period is given by the upper term on the right hand side of (4.11). It says that the value of stock per unit at the end of period t+1 is that period stumpage price subtracted by the carrying cost of stocks. The cost of shortage, given by the lower term, is the additional expences caused by the "emergency procurement" of the raw material during the production period subtracted by the capital loss or gain caused by the stumpage price change.

According to (4.11), the rise in the expected stumpage price increases both the value of terminal stock and the cost of shortage. Therefore, with rising stumpage price expectations, the firm is likely to reduce the risk of running out of stocks, whereas falling price expectations make the initial raw material stock smaller than otherwise, ceteris paribus. The important simplification made is that the unit costs q_t, r_{t+1} and $\bar{c}$ are not dependent on the level of stocks, k_{t+1}. Further more, it is assumed that $q_{t+1}-r_{t+1} > 0$ and $\bar{c}-(q_t-q_{t+1}) > 0$ so that the value of the stock and the cost of shortage are always positive quantities.

The penalty of shortage $\bar{c}$ lends itself to two alternative interpretations with respect to the cost of shortage. If the shortage means that part of the demand is simply unsatisfied, the effect of the shortage on future profits is determined by customers' reactions. Unsatisfied customers are likely to shop elsewhere in the future, thereby reducing the expected future profits. In this case, function ρ is an approximation of a more complicated formulation.

The second possibility, which is assumed to hold in the present case, is that the firm actually meets the shortage. This means that the firm can buy and use raw material during the same period. If the delivery lags are small and the costs of the raw material procurement during the production period are the same as during the previous period, it would not pay to carry stocks. The present model assumes, therefore, that it is more costly to acquire raw material during the production period than to add it to the stock before hand. In this case, ρ is actually an exact representation of the situation when the shortage occurs. The cost of shortage is the difference between the procurement during the period t and during the production period t+1 (Mills, 1962 p. 110).

4.1.4. Production costs

Because raw material is assumed to be the only scarce input, the production costs relevant to the expected profit maximizing firm are of the raw material costs. The total available supply during the period t+1 is determined by the available raw material during that period. Because an end of the period stock is possible, the raw material left from the previous period must also be taken into account. Available raw material during period t+1 is the stock left over from the previous period ($=k_t-\bar{u}_t$, where k_t is the beginning of present period stock and $\bar{u}_t$ is the given raw material consumption during present period) added to the purchases of the raw material during the present period t.

This results in the following stock identity

$$(4.12)\quad k_{t+1}-k_t=x_t-\bar{u}_t,$$

where x_t is the amount of sawlogs purchased during the period. The production function (4.4) then gives the maximum ex ante supply during period t+1.

The total production costs in the ex ante planning are the raw material costs added to the adjustment costs associated to the change in the level of stocks. The cost of the raw material is price times the amount purchased plus the timber procurement costs. The timber procurement costs are assumed constant and independent of the level of activity and are ignored. Stumpage markets are competitive, so that stumpage prices are independent of the amount purchased by the individual firm. The total cost function is now the following

$$(4.13)\quad tc_{prod} = q_t x_t + (n/2)(k_{+1}-k_t)^2.$$

The last term in (4.13) concerns the costs associated with the changes in the production level, e.g. timber procurement capacity is planned for some normal level and both over and under employment of the capacity costs. The same holds for the production capacity of sawnwood, although the capacity usage rate adjustment is fairly easy compared with many other branches of industry. These adjustment costs are presented here as a function of the change in the raw material stock (cf. Feige, 1967). Here n is a constant positive parameter, which gives the slope of the quadratic adjustment cost function.

Using the stock identity (4.12), and directly proportional production function (4.4), it is possible to write the purchased raw material x_t using present period planned and actual production and coming period planned production

$$(4.14) \quad x_t = k_{+1} - k_t + \bar{u}_t = y_{+1}/\alpha - y_t^*/\alpha + y_t/\alpha.$$

Here the coefficient of proportionality is used in order to present the raw material purchases as a function of the ex ante production y_{t+1}, the decision variable. The ex ante planned production of the present period y_t^* is not necessarily the same as the ex post realized production y_t. When deciding the period t+1 production both $y_t^*/\alpha = k_t$ and $y_t/\alpha = \bar{u}_t$ are given exogenous variables. Now the total cost of production can be explicitly written as a function of the decision variable y_{t+1}, the planned production as follows,

$$(4.15) \quad tc_{prod} = q_t(y_{+1}/\alpha - y_t^*/\alpha + y_t/\alpha) + (n/2)(y_{+1}/\alpha - y_t^*/\alpha)^2.$$

The marginal production cost, the derivate of the total cost function in (4.15) with respect to the planned production, y_{t+1}, is

$$(4.16) \quad mc_{prod} = q_t/\alpha + (n/\alpha)(y_{+1}/\alpha - y_t^*/\alpha).$$

In the next chapter the optimal ex ante production level will be derived using this marginal cost function and the expected marginal revenue function (4.9).

4.1.5. Ex ante raw material stock

The first order condition for the expected profits to be maximized is that marginal cost of production equals the marginal revenue. Substituting (4.11) into (4.9) and differentiating with respect to planned production, y_{t+1}, to get the expected marginal revenue (now using the explicit functional form of ρ)[6] and setting this equal to marginal costs from (4.16) results in

$$(4.17)\quad \bar{p}_{+1}\left[1-F(y_{+1}-\bar{z}_{+1})\right] + \frac{1}{\alpha}\left\{(q_{+1}-r_{+1})F(y_{+1}-\bar{z}_{+1}) + (\bar{c}-q_t+q_{+1})\left[1-F(y_{+1}-\bar{z}_{+1})\right]\right\} = \frac{1}{\alpha}\left[q_t + n(y_{+1}/\alpha - y_t^*/\alpha)\right].$$

In (4.17) the first term on the left hand side is price times the probability of shortage, that is price times the probability of being able to sell one more unit. The large bracket term on the left hand side gives the marginal value of the possibly remaining raw material stock at the end of the production period t+1. The first term in large brackets is the value of the terminal stock multiplied by the probability that production (dictated by the initial stock at t+1) exceeds the demand. The second term is the cost of shortage multiplied by the probability of shortage. The right hand side repeats the marginal cost (known with certainty) from (4.16).

In order to solve the optimal ex ante production level during the period t+1 (the optimal raw material stock level at the beginning of the period t+1) the distribution function F(.) is approximated by a linear function of its argument. This means that the frequency function is approximated by a constant (Mills, 1962 p. 131). For a general treatment of the present type of model see Arrow et al (1958). The frequency function is defined as follows (Mills, 1962 p. 96)

$$(4.18)\quad f(v) = \begin{cases} 0 & \text{when} \quad \xi < -\lambda \\ 1/2\lambda & \text{when} \quad -\lambda < \xi < \lambda \,, \\ 0 & \text{when} \quad \xi > \lambda \end{cases}$$

so that $F(a)=(a+\lambda)/2\lambda$, where $a=y_{t+1}-\bar{z}_{t+1}$. The equilibrium condition now becomes by substituting F(a) into equation (4.17)

$$(4.19)\quad \bar{p}_{+1}\left[1-(y_{+1}-\bar{z}_{+1}+\lambda)/2\lambda\right]+\frac{1}{\alpha}\left\{(q_{+1}-r_{+1})\left[(y_{+1}-\bar{z}_{+1}+\lambda)/2\lambda\right]\right.$$
$$\left.+(\bar{c}-q_t-q_{+1})\left[1-(y_{+1}-\bar{z}_{+1}+\lambda)/2\lambda\right]\right\}=\frac{1}{\alpha}\left[q_t+n(y_{+1}/\alpha-y_t^*/\alpha)\right].$$

This is the optimum production rule for the firm, and the ex ante stock can be explicitly solved as a function of the exogenous variables. Using the identity $y_{t+1}=\alpha k_{t+1}$ (which means that the firm ex ante plans the beginning of the production period stock to exactly match to the planned production) and $y_t^*=\alpha k_t$ and solving for k_{t+1} yields[5)]

$$(4.20)\quad k_{+1}=\frac{\lambda(\alpha\bar{p}_{+1}+2q_{+1}-3q_t-r_{+1}+\bar{c})}{B}+\frac{\alpha\bar{p}_{+1}+r_{+1}+\bar{c}-q_t}{B}\bar{z}_{+1}$$
$$+\frac{2\lambda n}{B}k_t,$$

where $B=\alpha(\alpha\bar{p}_{+1}+r_{+1}+\bar{c}-q_t)+2\lambda n$, and is always positive from the second order condition.[6)] Equation (4.20) is a linear approximation of a non-linear decision rule in (4.17) with respect to $\bar{z}_{t+1}$ and k_t, but it is still non-linear with respect to prices and costs. If the coefficients of $\bar{z}_{t+1}$ and k_t are assumed to be temporarily stable, an estimable function for k_{t+1} would be

$$(4.21)\quad k_{+1}=\kappa_0+\kappa_1\bar{z}_{+1}+\kappa_2 k_t.$$

Because B is positive and parameters α, n, and λ are also positive it follows that κ_1, $\kappa_2>0$. If the firm is a true monopolist, so that it can decide $\bar{p}_{t+1}$, then (4.20) along with the price equation (not derived here) provides sufficient approximation as is shown by Mills (1962 p. 132 and chapter 8). However, here both prices are beyond the control of the firm. For this reason their effect on the ex ante stock must be considered. Using the second order condition for the maximum, it is possible to examine the effects of prices and costs on the optimal ex ante raw material stock. Initially, however, the condition for beginning-of-production-period stock to be greater than required to produce the mean demand, is considered. First (4.20) is rearranged

$$(4.22)\ k_{+1} = \frac{\alpha\bar{p}_{+1} + r_{+1} + \bar{c} - q_t}{B}\left\{\bar{z}_{+1} + 2\lambda\left[\frac{1}{2} - \frac{(q_t - q_{+1}) + r_{+1} - n\,k_t}{\alpha\bar{p}_t + r_{+1} + \bar{c} - q_t}\right]\right\}.$$

In equation (4.22) $(1/\alpha)\bar{z}_{t+1}$ is the equilibrium raw material stock, when $\lambda = 0$, that is when there is no uncertainty. In the presence of uncertainty ($\lambda > 0$) the condition for the firm to want to produce the amount of mean demand or more, can be reduced to following[7)]

$$\alpha\,\bar{p}_{+1} \geq 3q_t - 2q_{+1} + r_{+1} + 2n((1/\alpha)\bar{z}_{+1} - k_t) - \bar{c}$$

In this case the right hand side of (4.22) is greater than or equal to $(1/\alpha)(\bar{z}_{t+1})$. Rearranging this condition to a more intuitive form

$$\alpha\,\bar{p}_{+1} \geq 2\,q_t + n((1/\alpha)\bar{z} - k_t) - (q_{+1} - r_{+1}) - (\bar{c} - (q_t - q_{+1})),$$

shows that final good price (multiplied by the coefficient of proportionality) has to be twice the marginal production cost (stumpage price) added to the marginal adjustment cost and subtracted by the marginal value of stock and the marginal cost of shortage. Only in this case it is profitable for the firm to buy enough raw material to produce at least the mean expected demand. When this condition does not hold the firm always buys less raw material ex ante than is required to produce the mean demand.

It is intuitively understandable that the above inequality is less likely to hold if the firm can not carry unused stock forward to following periods. In that case, the right hand side would be larger, because the stock would have no value at the end of the production period. The firm would, therefore be less likely to risk excess in stocks. The formal proof is omitted.

The condition also demonstrates the unsymmetrical effect of the adjustment costs. The firm is more likely to attempt to clear the markets if the initial stock (k_t) is large (large ex ante present period production) than if it is small compared to the following period expected mean demand. Also, the expected large stumpage price increases are likely to encourage the firm to risk excess stocks. Because other production costs than raw material costs have been ignored, the results can be considered to be only qualitative. For detailed discussion of the comparison between single period case and multiperiod case and between stochastic and certain cases in the present type of model, see Mills 1962, (chapters 5 and 6).

In order to consider the effects of exogenous variables on the optimal stock level k_{t+1} equation (4.20) is used. Both sides of (4.20) are multiplied by B and the comparative statics results of the model are obtained by implicit differentiation. Because the optimal decision rule for k_{t+1} is non-linear in prices and costs in empirical analysis some further approximations are required.

The implicit differentiation of (4.20) after multiplying both sides with B gives the following partial derivatives ($\lambda > 0$)

(4.23a) $$\frac{dk_{+1}}{dq_{+1}} = \frac{2\lambda}{B} > 0$$

(4.23b) $$\frac{dk_{+1}}{d\bar{z}_{+1}} = \frac{\alpha\bar{p}_{+1} + r_{+1} + \bar{c} - q_t}{B} > 0 \text{ when } \alpha p_{+1} + r_{+1} + \bar{c} > q_t$$

$$(4.23c)\quad \frac{dk_{+1}}{dk_t} = \frac{2\lambda n}{B} > 0$$

$$(4.23d)\quad \frac{dk_{+1}}{d\bar{p}_{+1}} = \frac{\alpha(\lambda + \bar{z}_{+1} - k_{+1})}{B} > 0 \quad \text{when } \lambda + \bar{z}_{+1} > \alpha k_{+1}$$

$$(4.23e)\quad \frac{dk_{+1}}{dq_t} = \frac{-3\lambda - \bar{z}_{+1} + \alpha k_{+1}}{B} < 0 \quad \text{when } 3\lambda + \bar{z}_{+1} > \alpha k_{+1}$$

$$(4.23f)\quad \frac{dk_{+1}}{dr_{+1}} = \frac{\bar{z}_{+1} - \lambda - \alpha k_{+1}}{B} < 0 \text{ when } \bar{z}_{+1} - \lambda < \alpha k_{+1}.$$

According (4.23) the ex ante beginning of the production period stock is an increasing function of the production period stumpage price (q_{t+1}), the production period mean demand ($\bar{z}_{t+1}$), initial stock level (k_t) and the production period sawnwood price ($\bar{p}_{t+1}$). It is a decreasing function of present stumpage price (q_t) and the carrying costs of stock (r_{t+1}).

The effect of the production period stumpage price and of the initial stock level are unambiguous, when there is uncertainty concerning the demand. The positive effect of the production period mean demand (expected demand) is conditional on the present period stumpage price being less than the final product price multiplied by the coefficient of proportionality and added to carrying costs of stocks and the penalty of shortage. This condition must hold, otherwise the firm would be producing with loss. If there are now adjustment costs, mean demand would affect the ex ante stock level directly by the amount of the inverted coefficient of proportionality of the production function (in that case $dk_{t+1}/d\bar{z}_{t+1}=1/\alpha$).

The signs of the effects of the sawnwood price and present period stumpage price are those given in (4.23d) and

(4.23e), at least, when $(1/\alpha)(\lambda+\bar{z}_{t+1}) > k_{t+1}$. Condition for this can be derived from (4.22) and is the following [8)]

$$q_{+1} < q_t + r_{+1} + n((1/\alpha)(\bar{z}_{+1} + \lambda) - k_t),$$

which means that high expected stumpage changes (or large initial stock) may reverse the signs of the comparative statics effects of sawnwood price and present period stumpage price. In the same way, the effect of the carrying cost of stock is negative as given in (4.23f) if $(1/\alpha)(\bar{z}_{+1} - \lambda) < k_{+1}$, which says that the firm is prepared to produce at least the amount it can sell under all circumstances.

This shows that the model behaves "well" only when the firm is planning production between the limits of minimum and maximum possible demand, i.e. in the interval $(\bar{z}_{+1} - \lambda, \bar{z}_{+1} + \lambda)$. But actually, the second order condition, $(B = \alpha(\alpha\bar{p}_{+1} + r_{+1} + \bar{c} - q_t) + 2\lambda n > 0)$, derived in note 6, only holds in this interval.

The above discussion shows that the model cannot properly handle the stumpage price expectations and the adjustment costs. Without them the planned production would necessarily stay between the limits of minimum and maximum possible demand. When the comparative static results are used for the implicit function for the beginning-of-production-period stock, it is assumed that adjustment costs and expected stumpage prices allow the solution to stay in the well defined area $(\bar{z}_{+1} - \lambda, \bar{z}_{+1} + \lambda)$.

If the periodization to present and coming (production) period had not been made, coming period stumpage price would not have entered the model. Because in empirical work the observation period used is fairly long (semi year) it is, however, reasonable to believe that stumpage price changes between two periods can be large enough to affect optimal decisions.

Indirectly, it is possible to test the intertemporal stability of the coefficients of (4.21), by first estimating the stock equation in that form. The following stage is then to add the price and cost variables and see whether some or all of them obtain statistically significant coefficients with the right signs. If this is not the case, (4.21) may provide a valid approximation.

4.2. Estimable stock adjustment and demand equations

Collecting the results from (4.23), the implicit complete equation for the beginning of the period stock becomes

$$(4.24) \quad k_{+1} = k(\underset{+}{z^e_{+1}},\ \underset{+}{p^e_{+1}},\ \underset{-}{q_t},\ \underset{+}{q^e_{+1}},\ \underset{-}{r^e_{+1}},\ \underset{+}{k_t}).$$

The variables with subscript t+1 are now denoted for empirical purposes with superscript e to distinguish from the fact that their real values are unknown in ex ante planning and some expected values must be used. Except the expected demand, expectation variables are due to the periodization used in the model. If one period model had been used and assumed that the raw material has to be bought at the beginning of the production period, the only expectation variable left would have been the expected demand. This would be a realistic assumption only for very short observation periods. The present formulation shows explicitly that in ex ante planning there is almost always some uncertainty concerning most exogenous variables, even though the present model handles these other variables as subjectively certain predictions.

Equation (4.24) gives the evolution of the beginning-of-production-period actual stock because the firm has already considered the adjustment costs while making the decision on k_{t+1}. Actually, (4.24) is a partial adjustment formula familiar from stock adjustment models. The desired or target stock k^*_{t+1} is in this case the stock when there is no adjustment costs (n=0).

The assumptions of the aggregation are discussed briefly in chapter 6.1. For the time being it is assumed that the requirements for aggregation are fulfilled so that the relationships derived for the representative firm can be used as such on the sectorial level. Capital letters are used for aggregated relationships. According to the stock adjustment model, the actual change in stocks is a fraction of the discrepancy between desired and actual stock. Error terms E_{1t} and E_{2t} are added to both the partial adjustment formula and to the desired stock equation (cf. Koutsoyiannis, 1977 p. 310).

(4.25) $$K_{t+1} - K_t = \delta(K^*_{t+1} - K_t) + E_{2t},$$

where $$K^*_{t+1} = \Theta_0 + \Theta_1 Z^e_{t,t+1} + \Theta_2 P^e_{t,t+1} + \Theta_3 Q_t + \Theta_4 R^e_{t,t+1} + \Theta_5 Q^e_{t,t+1} + E_{1t}.$$

By substituting for K^*_{t+1} in (4.25) and subtracting K_t from both sides, the equation for the beginning of the production period raw material stock becomes

(4.26) $$K_{t+1} = \delta\Theta_0 + \delta\Theta_1 Z^e_{t,t+1} + \delta\Theta_2 P^e_{t,t+1} + \delta\Theta_3 Q_{t,t+1} + \delta\Theta_4 R^e_{t,t+1} + \delta\Theta_5 Q^e_{t,t+1} + (1-\delta)K_t + \delta E_{1t} + E_{2t}$$

$$= \Phi_0 + \Phi_1 Z^e_{t,t+1} + \Phi_2 P^e_{t,t+1} + \Phi_3 Q_t + \Phi_4 R^e_{t,t+1} + \Phi_5 Q^e_{t,t+1} + (1-\delta)K_t + E_{3t}.$$

where $E_{3t} = \delta E_{1t} + E_{2t}$ and Φ:s are the coefficients to be estimated. This type of adjustment equation was probably first presented by Nerlove (1958), in search to avoid estimation difficulties of the Koyck distributed lag model. Using the stock identity, it is also possible to write the demand for the raw material during the period t, as follows

$$(4.27) \quad X_t^D = \bar{U}_t + K_{t+1} - K_t = \pi_0 + \pi_1 Z^e_{t,t+1} + \pi_2 P^e_{t,t+1}$$

$$+ \pi_3 Q_t + \pi_4 R^e_{t,t+1} + \pi_5 Q^e_{t,t+1} - \delta K_t + \bar{U}_t + E_{4t}.$$

This equation gives the demand as a linear function of exogenous and predetermined variables. The behavioral part of the equation is the same as in the stock equation above. The demand is therefore stock demand added to the consumption of the raw material during the present period. Because the desired change in the stocks may well be negative, it is possible that the demand of a period is smaller than the consumption of raw material in production. The error term E_{4t} is formally the same as E_{3t} in the stock adjustment equation. Both stock and demand equations will be estimated.

Notes on chapter 4:

1) Most of the sawnwood for export sales are produced to order. The capacity usage rate adjustment is relatively easy (although in reality not without costs). Therefore the representative firm can use the raw material (specially standing timber) stocks rather than finished goods stocks to buffer the fluctuating final product demand. However, the firm must have approximate knowledge about the quality, quantity and prices of the available raw material before completing the export sales.

As can be seen from appendix figure A12 (appendix 5, p. 127), there is a very strong seasonal pattern in export sales and in purchases of sawlogs. The purchases of sawlogs normally peak in late autumn. The export sales for the coming shipments period peak after this. Therefore, the decision concerning the purchases of sawlogs for coming period production are based on the expected sales and expected sawnwood prices of the coming shipments period.

Because only the ex ante decisions concerning the coming period production are considered, it is assumed that the firm knows the raw material requirement of the present period. The consumption of the raw material during the present period as well as the initial stock are given parameters when the ex ante production of the coming period is decided. The decision concerning coming period production therefore also uniquely determines the raw material which is bought into the stock to be used during the coming period.

Semiannual data is used in the empirical part of the study. While taking into account the seasonal pattern of sawnwood and sawlogs trade, the selection of a semiannual observation period is quite natural (although the available data does not actually permit shorter observation period). It might, however, be more realistic to model the firms behaviour differently for the first and second half of the year. Both in the sawnwood and sawlogs trade one might view autumn to be dominantly the ex ante planning period, while spring and early summer are the time for corrective ex post decisions. This would complicate both theoretical and empirical work considerably. The model used maybe best to describe the behaviour of large and middle sized export sawmills.

2) Another interpretation of the demand formulation (4.1) is that in the short run the firm actually has market power but "chooses not to change the price as long as the long run forecasts and the underlying cost considerations do not change" (Atkinson, 1981 p. 314).

3) Equivalence of (4.6) and (4.7) is seen by substituting $h(y_{t+1}, \bar{p}_{t+1})$ from (4.8) into (4.7) to get

$$E(tr)_{sales} = \bar{p}\,\bar{z} - \bar{p}\int_{y-\bar{z}}^{\infty} (v - y + \bar{z})f(v)dv$$

$$= \bar{p}_{+1}\bar{z}_{+1} - \bar{p}_{+1}\int_{y_{+1}-\bar{z}_{+1}}^{\infty} vf(v)dv - \bar{p}_{+1}(-y_{+1}+\bar{z}_{+1})\int_{y_{+1}-\bar{z}_{+1}}^{\infty} f(v)dv$$

$$= \bar{p}_{+1}\bar{z}_{+1} - \bar{p}_{+1}\int_{y_{+1}-\bar{z}_{+1}}^{\infty} vf(v)dv + (\bar{p}_{+1}y_{+1} - \bar{p}_{+1}\bar{z}_{+1})(1-F(y_{+1}-\bar{z}_{+1}))$$

$$= \bar{p}_{+1}\bar{z}_{+1} - \bar{p}_{+1}\int_{y_{+1}-\bar{z}_{+1}}^{\infty} vf(v)dv + \bar{p}_{+1}y_{+1} - \bar{p}_{+1}\bar{z}_{+1} - \bar{p}_{+1}y_{+1}F(y_{+1}-\bar{z}_{+1})$$
$$+ \bar{p}_{+1}\bar{z}_{+1}F(y_{+1}-\bar{z}_{+1}).$$

Because $\int_{-\infty}^{y_{+1}-\bar{z}_{+1}} vf(v)dv + \int_{y_{+1}-\bar{z}_{+1}}^{\infty} vf(v)dv = 0$, (4.7) follows

$$(4.7) \quad E(tr)_{sales} = \bar{p}_{+1}\bar{z}_{+1}F(y_{+1}-\bar{z}_{+1}) + \bar{p}_{+1}\int_{-\infty}^{y_{+1}-\bar{z}_{+1}} vf(v)dv$$
$$+ \bar{p}_{+1}y_{+1} \left[1-F(y_{+1}-\bar{z}_{+1})\right].$$

4) The derivative of function h(.) in (4.9) with respect to planned production is obtained as follows

$$\frac{\partial h}{\partial y_{+1}} = \frac{\partial}{\partial y_{+1}} \int_{y_{+1}-\bar{z}_{+1}}^{\infty} (v-y_{+1} + \bar{z}_{+1}) f(v)dv$$

$$= -(v-y_{+1}+\bar{z}_{+1}) f(y_{+1}-\bar{z}_{+1}) + \int_{y_{+1}-\bar{z}_{+1}}^{\infty} \frac{\partial}{\partial y_{+1}}(v-y_{+1}+\bar{z}_{+1}) f(v)dv.$$

At the limit $(v-y_{+1}+\bar{z}_{+1}) = 0$, and therefore the derivate of h with respect to y_{t+1} is

$$\frac{\partial h}{\partial y_{+1}} = -\left[1-F(y_{+1}-\bar{z}_{+1})\right].$$

Here, and below in note 6, the following rule of differentiating definit integrals is used. Suppose

$$I(\alpha) = \int_a^b f(x,\alpha)dx,$$

where $f(x,\alpha)$ is an integrable function of x in the range $a \leq x \leq b$, and a and b are in general continuous and at least once differentiable functions of α. Then it is possible to show that

$$\frac{\partial I(\alpha)}{\partial \alpha} = f(b,\alpha)\frac{db}{d\alpha} - f(a,\alpha)\frac{da}{d\alpha} + \int_a^b \frac{\partial f(x,\alpha)}{\partial \alpha} dx.$$

See for example Stephenson (1973 p. 182). If the limits of integration do not depend on α, then

$$\frac{d}{dx}\left\{\int_a^b f(x,\alpha)dx\right\} = \int_a^b \frac{\partial f(x,\alpha)}{\partial \alpha} dx.$$

5) Probably the easiest way to derive (4.20) is to manipulate (4.17) to get

$$\bar{p}_{+1}-2q_t+q_{+1}+\bar{c}-n(y_{+1}/\alpha \; -y_t^*/\alpha \;)$$
$$= (\;\alpha\bar{p}_{+1}+r_{+1}+\bar{c}-q_t)F(y_{+1}-\bar{z}_{+1}).$$

Substituting $k_{+1}=y_{+1}/\alpha$, $k_t=y_t^*/\alpha$ and $F(y_{+1}-\bar{z}_{+1})=(y_{+1}-\bar{z}_{+1}+\lambda\;)/2\lambda$ and rearranging leads to (4.20).

6) The derivation of the second order condition for expected profits to be maximized is given below. First (4.9) is written out in integral form and differentiated to obtain expected marginal revenue E(mr) given in (4.9). Here the explicit form of function ρ is used according the fact that

$$\rho \;=\; \begin{cases}(1/\alpha\;)(q_{+1}-r_{+1})(y_{+1}-\bar{z}_{+1}-v), \text{ when } v\le y_{+1}-\bar{z}_{+1} \\ (1/\alpha\;)(\bar{c}-(q_t-q_{+1}))(y_{+1}-\bar{z}_{+1}-v), \text{ when } v>y_{+1}-\bar{z}_{+1}.\end{cases}$$

The expected total revenue is therefore

$$E(tr) = \bar{p}_{+1}\bar{z}_{+1} - \bar{p}\int_{y_{+1}-\bar{z}_{+1}}^{\infty}(v-y_{+1}+\bar{z}_{+1})f(v)dv + \int_{-\infty}^{y_{+1}-\bar{z}_{+1}} b_1(y_{+1}-\bar{z}_{+1}-v)f(v)dv$$

$$+ \int_{y_{+1}-\bar{z}_{+1}}^{\infty} b_2(y_{+1}-\bar{z}_{+1}-v)f(v)dv \;;\; b_1 = (q_{+1}-r_{+1})/\alpha \text{ and } b_2 = (\bar{c}-q_t-q_{+1})/\alpha .$$

Expected marginal revenue from sales is then, when the total revenue is differentiated with respect to the planned production, y_{t+1}

$$E(mr) = \bar{p}_{+1}\int_{y_{+1}-\bar{z}_{+1}}^{\infty} f(v)dv + \int_{-\infty}^{y_{+1}-\bar{z}_{+1}} b_1 f(v)dv + \int_{y_{+1}-\bar{z}_{+1}}^{\infty} b_2 f(v)dv$$

$$= \bar{p}_{+1}\;[1-F(y_{+1}-\bar{z}_{+1})] + b_1\;F(y_{+1}-\bar{z}_{+1}) + b_2\;[1-F(y_{+1}-\bar{z}_{+1})].$$

Differentiating this with respect to y_{t+1} gives

$$\frac{\partial}{\partial y_{+1}}E(mr) = \frac{\partial}{\partial y_{+1}}\left\{ \bar{p}_{+1}\int_{y_{+1}-\bar{z}_{+1}}^{\infty} f(v)dv + \int_{-\infty}^{y_{+1}-\bar{z}_{+1}} b_1 f(v)dv \right.$$

$$\left. + \int_{y_{+1}-\bar{z}_{+1}}^{\infty} b_2 f(v)dv \right\} = -\bar{p}_{+1}f(y_{+1}-\bar{z}_{+1}) + (b_1-b_2)f(y_{+1}-\bar{z}_{+1}).$$

From marginal cost function (4.16) by differentiating with respect to y_{t+1} follows,

$$\frac{\partial}{\partial y_{+1}} mc = \frac{1}{\alpha^2} n.$$

For expected profits to be maximized

$$\frac{\partial}{\partial y_{+1}} E(mr) - \frac{\partial}{\partial y_{+1}} mc < 0$$

must hold, therefore

$$-\bar{p}_{+1} f\,(y_{+1}-\bar{z}_{+1}) + (b_1-b_2) f(y_{+1}-\bar{z}_{+1}) - n/\alpha^2 < 0.$$

Using the approximation of f(v) in (4.18) on p. 27 we get for the closed interval $[-\lambda, \lambda]$,

$$-\bar{p}_{+1}(1/2\lambda) + (b_1-b_2)(1/2\lambda) - n/\alpha^2 < 0.$$

Substituting for b_1 and b_2 this finally leads to

$$\alpha\bar{p}_{+1} - q_t + r + c + 2\lambda n/\alpha > 0.$$

Outside $[-\lambda, \lambda]$ the second order condition is $n/\alpha^2 > 0$, but only the case $f(v) > 0$ is considered.

7) The condition for $k_{t+1} \geq (1/\alpha)\bar{z}_{t+1}$ is obtained by demanding that

$$(1/\alpha)\bar{z}_{+1} \leq \frac{\alpha\bar{p}_{+1} + r_{+1} + \bar{c} - q_t}{B} \left\{ \bar{z}_{+1} + 2\lambda \left[\frac{1}{2} - \frac{(q_t - q_{+1}) + r_{+1} - n\,k_t}{\alpha\bar{p}_t + r_{+1} + \bar{c} - q_t} \right] \right\},$$

where $B = \alpha(\alpha\bar{p}_{+1} + r_{+1} + \bar{c} - q_t) + 2\lambda n,$

and the right hand side is equal to the right hand side of (4.22). Multiplying the large bracket term with its coefficient on the right hand side this leads after some manipulation

$$\bar{p}_{+1} \geq 3q_t - 2q_{+1} + r_{+1} + 2n((1/\alpha)(\bar{z}_{+1} - k_t) - \bar{c}.$$

8) The condition for $(1/\alpha)(\lambda + \bar{z}_{t+1}) > k_{t+1}$ can be derived by demanding that

$$(1/\alpha)(\lambda + \bar{z}_{+1}) >$$

$$\frac{\alpha\bar{p}_{+1} + r_{+1} + \bar{c} - q_t}{B} \left\{ \bar{z}_{+1} + 2\lambda \left[\frac{1}{2} - \frac{(q_t - q_{+1}) + r_{+1} - n\, k_t}{\alpha\bar{p}_t + r_{+1} + \bar{c} - q_t} \right] \right\}.$$

As above the right hand side is the same as in (4.22). After some manipulation this reduces to

$$q_{+1} < q_t + r_{+1} + n\left[(1/\alpha)(\bar{z}_{+1} + \lambda) - k_t\right].$$

5. SUPPLY OF SAWLOGS

5.1. Steady state model of the roundwood supply

The present investigation of the roundwood markets concerns the short run sawlog supply and its determinants. Therefore, only a short review of the main results of the optimum rotation literature is given in order to provide a reference to the short run 'disequilibrium' problems.

The optimal rotation thinking was initiated as early as 1849 by the Austrian Martin Faustmann. Samuelson (1976) showed that the Faustmann formula is the only correct way to determine the economically optimal rotation over an infinite number of rotation cycles. The optimal age of the harvest is that which maximizes "the present discounted value of all net cash receipts excluding explicit or implicit land rents but calculated over the infinite chain of cycles of planting on a given acre of land from now until Kingdom Come" (Samuelson, 1976 p. 471). This is the equivalent of maximizing discounted value of net algebraic receipts over the first cycle, but including the market land rental in those receipts (op cit, p. 472).

Suppose competitive markets, perfect foresights and perfect capital markets and no production costs, then the discounted value of the future returns in continuous time is

$$(5.1)\ pv(t)=qs(t)\exp(-it)[1+\exp(-it)+(\exp(-it))^2+,\ldots\quad],$$

which is equal to

$$(5.2)\ pv(t)=(qs(t)\exp(-it))/(1-\exp(-it)),$$

where pv - present discounted value of all future returns from the forest land (=stumpage income, in this case)

q - stumpage price

i - return from alternative investment

s - stock of standing timber per unit of land

t - rotation period (in continuous time)

Equation (5.1) is the correct Faustman - Gaffney - Hirshleifer formula without labour and other input costs (Samuelson, 1976 p. 479). The powers 1, 2,... in square brackets of (5.1) refer to rotation cycles.

The first order condition for the maximum of pv_t is

(5.3) $s'(t)/s(t)=i/(1-\exp(-it))$,

which is obtained from (5.2) by differentiating it with respect to time. This shows that the optimal financial maturity is independent of the market price of timber in natural forests. Adding silvicultural costs to the model makes the optimum rotation shorter thereby reducing the long run timber "supply". With silvicultural costs in the model, every increase in the stumpage price increases supply in the short run, but the long run supply will decrease as a result of shorter optimum rotation age caused by the price increase (cf Hyde, 1980 p. 60). If the land area is allowed to vary and land markets are perfect, timber supply in the long run also becomes an increasing function of time. This derives from the fact that increasing stumpage prices bid up the land prices, thereby allocating more land to forestry (cf Knapp, 1981 chapter III).

Optimum rotation models are only concerned with steady states and do not deal with short run adjustments in which the present study is interested.

In the short run, for example, standing stock need not be in long run equilibrium. Also, income from the forestry is usually not the only income source to the forest owner. In the short run, stumpage income from the forestry is in many cases the most flexible income source, the use of which is affected by the exogenous changes in other incomes. The effects of these, in the short run, exogenous variables on the sawlog supply will be discussed in the next section.

5.2. Sawlog supply in the short run

5.2.1. Introduction

The production of sawlogs is a joint product problem in several respects. More than half of the forest owners in Finland are farmers. For a farmer, roundwood production is often an integrated part of the income flow of the farm. Investments in machinery can in many cases be used both in agriculture and forestry and stumpage income is often used as the source of finance of these investments. Further more, the woodlot also produces other outputs than roundwood. These material or nonmaterial nontimber outputs probably also affect the forest management decisions.

In the steady state timber supply models (cf. Knapp, 1981), perfect markets of the forest land cause efficient allocation of resources in cases where amenity markets are imperfect. The land prices are affected by stumpage income and the imputed income from amenities.

For legislative and institutional reasons it is not necessary to own forest land in Finland in order to be able to use a part of the non-timber outputs of the forests (for example berry picking and recreation). On the other hand, there are values associated to the stock of standing timber which affect the forest management decisions, but which are difficult or impossible to measure. Even if part of the amenities had markets, some of the non-material values of the forest stand to the owner will remain outside the market system, but still affect the supply of timber. For example, emotional values of the forest and the security given by the standing stock (and negative attitudes towards clear cut areas) are difficult to quantify but undoubtedly affect the supply.

Only the combined production of timber (sawlogs) and nontimber outputs of the forests are considered in the present study. Also, the possibility that sawmill firms own forests will be ignored.

The disregard of combined agriculture and forestry is of course a severe simplification. A related problem is that the life cycle planning and possibility of savings will not be considered. These features would normally be important both for farmers and forest farm owners. One can well imagine that the forest owner, who is, for example rationed in the capital or labor markets, manages his forests differently than the one who faces perfect markets.

These problems are related to the model of "self active forest farmer" presented by Löfgren and Johansson (1982). This model presents the problem of the forest owner who can allocate his working hours between industry, agriculture and forestry. After presenting a model with perfect markets, where the supply of roundwood is concluded to be nondecreasing function of its price, also a problem with income constraints is considered. They conclude that the backward bending supply curve for roundwood seems to be result of the assumption that income constraint can only be satisfied with income from forestry. Very institutionalized working hours in industry may actually make this type of behaviour not too unrealistic (op cit, p. 163).

The flow of stumpage income is controlled by the forest owner through sales and management decisions. Timber production costs are small, and at present in Finland, the only costs of major importance are the lump sum area tax paid by the forest owner for the forest property together with explicit or implicit capital costs. Other income (labour or agricultural income) is often more or less exogenous to the forest owner after the initial decision to participate the labour force has been made (institutionalized working hours). The flexibility of the stumpage income in the short run is therefore of great importance to the forest owner.

Undoubtedly the security against inflation given by the forest property also affects the management decisions. The stock of standing timber is actually an asset in the forest owner's portfolio. Therefore rate of return from alternative investment and short run price changes (and price expectations) can be important determinants of the short run forest management decisions.

The above discussion suggest that the short run supply of sawlogs can be derived using different type of approaches, depending on, which features of the problem are considered most relevant. For example, the asset motive would suggest an approach where the forest owner is maximizing the present value of stumpage sales income assuming that all markets are perfect.

If the income constraints and imputed utility of the forest property are considered important the approach might rather be the one, where the forest owner is maximizing utility derived from consumption of goods and services and from nontimber outputs of the forest property. Both utility maximizing and present value maximizing approaches will be discussed. It will be demonstrated, however, that the model of the present value maximizer is only a special case of intertemporal utility maximizing model under certain assumptions.

Before presenting the present value maximizing approach it is finally noted that also the pulpwood production is ignored in the present study. The production of sawlogs is not possible without the production of a certain amount of pulpwood. Ignoring pulpwood production means that sawlog prices and sales dominate the forest management decisions. In most of the cases, this assumption is probably justified, but of course it is an oversimplification. Thinnings, when only pulpwood is sold, form but a small part of the total commercial fellings (in 1979 thinnings were 28.5 % of the total area harvested).

5.2.2. Present value approach

The discussion in this and in the next section serves as the basis for the estimable sawlog supply equation. Therefore the term sawlog is used, even if the model makes no difference between sawlog trees and pulpwood and the model could actually be used in the situation were the forest owner is planning the production of all roundwood (both sawlogs, pulpwood and fuelwood). Perfect capital and sawlog markets are assumed and the forest owner does not consider outputs of the forest other than sawlogs. Suppose that the forest owner is maximizing the present value of his sawlog sales during the arbitrary planning horizon (t=1,.. T). The problem is therefore

$$(5.4)\ \text{Max } pv_t = \sum_{t=1}^{T} (1+i)^{1-t} q_t x_t$$

subject to

$$(5.5a)\ s_t = s_{t-1} + g(s_{t-1}) - x_t$$

and

$$(5.5b)\ s_T = \hat{s} > 0,$$

where

pv_t - Present value of stumpage income
i - forest owners time preference
s_t - standing stock at the end of period t per unit of land
q_t - market stumpage price
x_t - sawlog sales
g - strictly concave growth function.

The forest owner is constrained by the standing stock identity relating growth and cuttings to the evolution of stock over time (5.5a). The end of planning period stock is constrained to some positive constant ($\hat{s}_t$) assuming that the forest owner puts a value on the terminal stock and therefore does not cut it all at time T. The constraint (5.5b) is not formally considered because it does not affect the qualitative empirical implications of the model.

The following assumptions are made about the growth function

$g'=g_s \geq 0$ when $s \leq \bar{s}$
$g'=g_s < 0$ when $s > \bar{s}$
$g''=g_{ss} > 0$ when $s < s^1 < \bar{s}$ and $s > s^2 > \bar{s}$
$g''=g_{ss} \leq 0$ when $s^1 \leq s \leq s^2$.

Stock giving maximum biological yield is denoted by $\bar{s}$. Only the concave section of the growth function ($s^1 \leq s \leq s^2$) is considered (figure 3). The representative forest owner follows regulated, uneven aged forest management so that on average his forest is neither extremely young (standing volume close to zero) nor very old (very large volume per hectare). In the present model standing stock, s, includes all vintages from bare land to the oldest age class. For the purposes of the short term model, this is considered a sufficient approximation. Equation (5.5a) is the standing stock identity. The sawlog supply in the short run is constrained by the initial stock of each planning period. The greater the stock at the

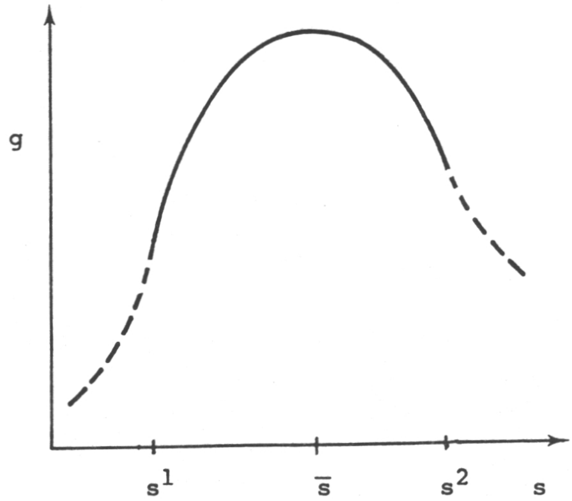


Figure 3. Growth as a function of standing stock.

beginning of the period compared with the end of the period optimum stock, the greater will be the supply of sawlogs during that period. This is seen from the stock identity when the end of the period short run equilibrium stock is denoted by s_t^* so that

$$s_t^*=s_{t-1}+g(s_{t-1})-x_t.$$

If $s_t^*>s_{t-1}$, it is clear that the cuttings are increased by increasing s_{t-1} as long as $g'(s_{t-1})$ is positive. If s_{t-1} is already at the optimal level with respect to the exogenous variables, growth and cuttings will be equal. If the forest owner renews the future management plan at the beginning of each period, s_{t-1} is given parameter in each period. The objective function (5.4) gives the present value of the future stumpage incomes in competitive markets. The Lagrangean of the model is

$$(5.6)\quad L=\sum_{t=1}^{T}(1+i)^{1-t}q_t x_t-\sum_{t=1}^{T}\mu_t(s_t-s_{t-1}-g(s_{t-1})+x_t)),$$

and the first order conditions for the maximum are

$$(5.7a)\quad \frac{\partial L}{\partial x_t} = q_t(1+i)^{1-t} - \mu_t = 0$$

$$(5.7b)\quad \frac{\partial L}{\partial s_t} = -\mu_t + \mu_{t+1}(1+g') = 0$$

$$(5.7c)\quad \frac{\partial L}{\partial \mu_t} = -s_t + s_{t-1} + g(s_{t-1}) - x_t = 0.$$

Substituting for μ_t and μ_{t+1} in (5.7b) from (5.7a) the following equilibrium condition is obtained

$$(5.8)\quad q_t(1+i) = q_{t+1}(1+g')\ ;\quad g' = \frac{\partial g}{\partial s_t}.$$

Because time is the only production input the equilibrium condition has an intuitive interpretation.[1] Given exogenous prices, (q), and the time preference, (i), the condition (5.8) equates the marginal cost of one unit of input to the marginal revenue obtained from using that additional input. The marginal cost on the right hand side is the current stumpage price multiplied by the time preference (the interest rate in competitive capital markets). Marginal revenue is the coming period stumpage price times the change in growth rate resulting from the change of the stock level at time t.

Condition (5.8) is the implicit sawlog supply function of the present value maximizer of the stumpage income. Implicit differentiation of the equilibrium condition gives the comparative statics of the model. By substituting s_t from (5.5a) into equilibrium condition

$$(5.8')\quad q_t(1+1) = q_{t+1}\left[1+g'(s_{t-1}+g(s_{t-1})-x_t)\right],$$

and differentiating, the effect of present period, stumpage price on sawlog sales becomes

$$(5.9)\quad \frac{dx_t}{dq_t} = -\frac{1+i}{q_{t+1}g''}.$$

The denominator is negative because g'' is negative, when g is strictly concave (as required for the second order condition for maximum to hold). The numerator is always positive. Therefore expression is unambiguously positive in the concave section of the growth function. The higher the stumpage price during this period the higher will be the short run supply in order to get the end of period stock at the equilibrium level. When stumpage price increases, part of the stock must be liquidated to restore the equilibrium. Sawlog supply increases in the short run, but only in the short run.

The effect of the coming period stumpage price on the present period sawlog sales is as follows

$$(5.10) \quad \frac{dx_t}{dq_{t+1}} = \frac{1+g'}{q_{t+1}g''}.$$

This expression is negative when both first and second order conditions for the maximum hold. Intuitively, it says that higher stumpage prices in the future increase marginal revenue of future production and therefore it is profitable to allocate production to that period. Actually, a rise in q_{t+1} means a relative decrease in q_t and an increase in the end of period optimal stock, so that the short run sawlog supply decreases.

An increase in the forest owner's time preference quite naturally increases the present period supply. This is indicated by

$$(5.11) \quad \frac{dx_t}{di} = - \frac{i}{q_{t+1}g''},$$

which is positive. Therefore the higher the time preference of the forest owner the lower the end-of-period optimum stock.

The effects of the exogenous variables have been calculated with respect to sales. Imposing the constraint to the maximizing problems gives the Lagrange multiplier μ, which has a convenient interpretation. It gives the shadow value of the stock to the forest owner. It would have been equally possible to substitute the value of x_t solved from the constraint (5.5a) to the present value function directly. In this case the function to be maximized would be

$$(5.12)\quad pv_t=\sum_{t=1}^{T}(1+i)^{1-t}q_t(s_{t-1}+g(s_{t-1})-s_t).$$

This representation has the advantage that it explicitly shows that the forest owner actually has only one independent decision variable s_t. Being a neoclassical decision maker, the forest owner during the first period decides simultaneously the optimal levels of all future periods standing stocks. Therefore, only the beginning of the first period standing stock s_0 is exogenously given. If, however, we assume, not unrealistically, that the plan is revised at the beginning of each period, given the currently available information the partial derivate dx_t/ds_{t-1} (or ds_t/ds_{t-1}) can also be calculated from (5.8'). The effect of the beginning of the period stock on supply is positive as long as the stock increase does not lead to decrease in growth. This is seen from

$$(5.13)\quad \frac{dx_t}{ds_{t-1}}=\frac{q_{t+1}g''(1+g')}{q_{t+1}g''},$$

which is positive. Implicitly including (5.13) in the comparative statics of the model means that there are some adjustment costs associated with the changes in the stock level, so that successive stock levels become positively autocorrelated. This seems a very realistic assumption when considering the nature of the resource and its management.

The above comparative static results are illustrated in figure 4. Rearrange (5.8) to get

$$(5.14)\quad (q_t(1+i))/q_{t+1}=1+g'.$$

The left hand side of the equation (5.14) is equal to one if $q_t(1+i) = q_{t+1}$. This is depicted by the straight line in figure 4. The curve (1+g') is equal to one at the level of the standing volume giving the maximum biological yield (g'=0).

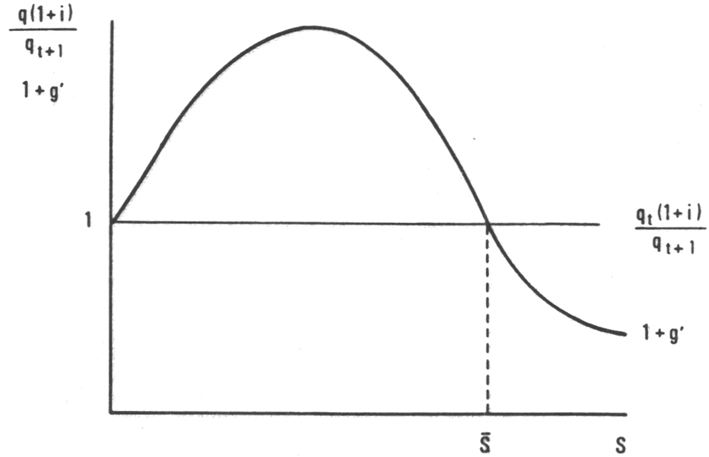


Figure 4. Present value maximizer's equilibrium condition.

From figure 4 it can be seen that an increase in q_t or i makes the ratio $q_t(1+i)/q_{t+1}$ greater than one and the equilibrium stock at the end of the period t decreases, thereby increasing the sawlog supply in the short run. If the expected stumpage price decreases, this ratio becomes smaller and the equilibrium stock increases, thereby decreasing the short run supply.

The standing stock, $\bar{s}$, is actually a long run steady state equilibrium when the real interest rate is zero because in steady state prices are constant. In a model with no variable production costs the financial maturity is solely determined by the interest rate if $q_t=q_{t+1}$. In the present model, therefore, all non-zero interest rates result in an economically optimal sawlog supply in the long run which is below the biological maximum yield. Notice that the equilibrium condition is not the same as that in Faustmann formula (p. 41), because the planning horizon is finite and the land rent is not considered. (For a discussion on the effects of negative interest rate in the optimal rotation model see Löfgren and Johansson (1982 pp. 116-118)).

5.2.3. Utility approach

If, instead of maximizing the present value of sawlog sales, the forest owner maximizes utility over the planning horizon, the previous comparative statics results become less obvious. The problem is considered in this section. I suppose the forest owner is now maximizing his utility over some planning period (life cycle, forest management plan's duration) of length T. This utility depends on the consumption of goods and services (c_t) and on the services (amenities) of the forest land, e.g. as a source of physical and spiritual recreation, etc, assuming that the latter services are proportional to the standing stock at the forest land at the end of each period, s_t The forest owner's problem is therefore

$$(5.15)\quad \text{Max } U = \sum_{t=1}^{T} (1+i)^{1-t} u(s_t, c_t).$$

This utility function is closely related to the one used by Binkley. He considered one period model, where the utility was an increasing function of consumption of goods and services and the non-tradable amenity values of the forest land. The latter were defined to be a decreasing function of the amount of timber cut and an increasing function of forest land area, with nonpositive second and negative or positive cross derivatives (Binkley, 1981 p. 33). Utility function (5.15) has the normal properties of being diminishingly increasing with respect to both of its arguments, so that

$u_c, u_s > 0$; $u_{cc}, u_{ss} < 0$ and $u_{cs} \geq 0$.

The forest owner is constrained by the budget and the standing stock identities,

(5.16a) $p_t c_t = (m_t + q_t x_t)$

and

(5.16b) $s_t = s_{t-1} + g(s_{t-1}) - x_t$,

where m_t - exogenous income
q_t - stumpage price
x_t - sawlog sales
p_t - price of goods and services
c_t - goods and services consumed
s_t - standing volume of the forest per unit of land at the end of period t
g - strictly concave growth function.

Exogenous income and prices are both given. Implicitly, as above, the only input used in the sawlog production is time. The model therefore strictly only concerns natural forests. (The silvicultural costs are about 15 - 25% of the stumpage income in Finland (Seppälä et al., 1980 p. 102)). The complication introduced by the forest taxation and capital costs of sawlog production is ignored.

The budget constraint (5.16a) says that consumption in each period must be equal to income, which consists of exogenous income and stumpage income from sawlog sales. The standing stock identity gives the upper limit to the sales in the short run. If exogenous variables were constant over time, cuttings would settle to equilibrium level as is the case in the optimum rotation models.

The Lagrangean of the forest owner's maximizing problem becomes

$$(5.17)\ L = \sum_{t=1}^{T} (1+i)^{1-t} u(s_t, m_t+q_t x_t) - \sum_{t=1}^{T} \mu_t (s_t - s_{t-1} - g(s_{t-1}) + x_t).$$

In (5.17) the budget constraint has been normalized by dividing by p_t, and the money value of the consumption of goods and services has been inserted into the utility function. The first order conditions for the maximum are as follows

$$(5.18a)\ \frac{\partial L}{\partial s_t} = (1+i)^{1-t} u_1 - \mu_t + \mu_{t+1}(1+g') = 0$$

$$(5.18b)\ \frac{\partial L}{\partial x_t} = -(1+i)^{1-t} u_2 q_t - \mu_t = 0$$

$$(5.18c)\ \frac{\partial L}{\partial \mu_t} = -s_t + s_{t-1} + g(s_{t-1}) - x_t = 0.$$

The derivates of the utility function with respect to its first (s_t) and second (c_t) argument are denoted by u_1 and u_2 respectively. The first derivate of the growth function with respect to standing volume (s) is denoted by g'. Forest owners' equilibrium condition is therefore

$$(5.19)\ u_1^t = u_2^t q_t - (1+i)^{-1}(1+g') u_2^{t+1} q_{t+1}.$$

This equilibrium condition is obtained by substituting for μ_t and μ_{t+1} in (5.7a) solved from (5.7b). Superscript (t+1) is used to remind us that the first partial derivative of the utility function now has the coming period values as arguments.

The equilibrium condition says that the utility gain given by the increase in consumption possibilities must be sufficient to offset the utility loss caused by the decrease in the consumption possibilities of nontimber outputs. This equilibrium condition includes the present value maximizer's equilibrium condition (5.8) as a special case and reduces to it when $u_1^t=0$ (the stock imputes no utility to the owner) and $u_2^t=u_2^{t+1}=1$ (the marginal utility of consumption is equal to one). It is again the implicit sawlog supply function of the utility maximizing forest owner. Unfortunately, in an intertemporal setting it does not give signs to the effects of exogenous variables on the optimal supply of sawlogs. Appendix 1 discusses the problem using a two period model and outlines the solution in a general case.

If the intertemporal feature is ignored so that only one period at the time is considered, the problem is similar to the one considered by Binkley (1981 p. 30). He, however, related the nontimber outputs and their consumption to the forest land area and to the amount timber cut, not to the standing stock as is done in the present study. The problem in one period case can be stated as

$$(5.20)\quad \text{Max } u=u(s,c)=u(s_0+g(s_0)-x,m+qx),$$

so that the first order condition gives the implicit sawlog supply function in a particularly simple form

$$(5.21)\quad u_1=u_2q.$$

This of course is only a special case of (5.19). Differentiating, and noting that s_0 is a given parameter, (5.21) gives the supply of sawlogs as a decreasing function of income, m, increasing function of initial stock, s_0, and increasing or decreasing function of stumpage price, q . This is seen from comparative statics of the model which are

$$(5.22a)\quad \frac{dx}{dq} = \frac{-u_{12}x+u_{22}qx+u_2}{-u_{11}+2u_{12}q-u_{22}q^2} \lesseqgtr 0$$

$$(5.22b)\quad \frac{dx}{dm} = \frac{-u_{12}+u_{22}q}{-u_{11}+2u_{12}q-u_{22}q^2} < 0$$

$$(5.22c)\quad \frac{dx}{ds_0} = \frac{(u_{12}q-u_{11})(1+g')}{-u_{11}+2u_{12}q-u_{22}q^2} > 0,$$

when $-u_{11}+2u_{12}q-u_{22}q^2$ is positive (from the second order condition).

In the one period model, the effects of exogenous income and the beginning of period stock are unambiguous. An increase in exogenous income reduces the supply, and an increase in the initial stock increases it. In this case, however, the effect of stumpage price remains ambiguous, because substitution and income effects work into different directions. The income effect is partly due to the inclusion of the imputed utility of the stock (u_{12}), but the other part (u_{22}) remains, even if the stock, as such, imputes no utility to the forest owner. In the short run it is reasonable to believe that the substitution effect dominates. Only in such cases where the stumpage income is a marginal income source may the effect of stock's imputed utility have practical significance in the timber management decisions. (see Binkley 1981, p. 36).

In the present framework this is almost all that can be said. If the dynamic standing stock constraint is imposed on the model and a period of arbitrary length (1,.. T) is considered, all comparative statics results become ambiguous. However, appendix 1 shows that if only two periods are considered, the supply of sawlogs is still an increasing function of the present period stumpage price, the forest owner's time preference and the initial stock and a decreasing function of exogenous income and an increasing or decreasing function of second period's stumpage price and exogenous income.

In the two period case, one can interpret the model in such a way that the forest owner initially makes the optimal plan for periods 1 to 2. The next plan only considers periods 2 to 3 and so forth. Actually, this is not an unrealistic approach. Earlier, in the model of the present value maximizer, the same assumption was actually made by including the effect of lagged stock (s_{t-1}) to comparative static results. Only in a steady state model the initial plan simultaneously determines optimal stock levels of all future periods, in which case only the initial stock (s_0) is exogenous. This means that no adjustment costs exist which in a short term model is not a very realistic assumption.

An important feature of the intertemporal model is that the ambiguity of the results is independent of the form of the utility function, as long as the realistic assumptions of the positive first derivatives and negative second derivatives and non-negative cross effects are not abandoned. Further eliminating the stock's imputed utility does not make the results any more precise. Therefore, it is not the imputed utility of the stock alone which causes the problems. It is the utility maximization in the intertemporal setting with the dynamic standing stock constraint that binds the successive periods decisions. This dynamic constraint actually makes the problem more complicated than the standard consumer choice in the intertemporal setting.

The present value maximizer would probably cut the remaining stock during the last period without additional constraint on the end of planning horizon stock. But when the imputed utility of the stock is in the model this is not necessarily the case. This gives a slightly wider perspective to the value of the terminal stock. Actually, the utility maximizer's assessment of his remaining stock may be very similar to the assessment of remaining stock by the above representative firm. The stock has value to him not only because it imputes utility during the present period, but also (maybe more importantly) because it affects his expectations of future utilities.

Interpreting the terminal stock as an argument in the expected utility function would mean that the utility is a function of present period events added to the function of stock that gives the effect of present activities on expected future utilities. This, of course, means that the activities are also assumed to continue after present period. Then, for example, the expectations of future non-stumpage incomes and stumpage prices would show in the imputed utility of the end of period stock. Formal consideration of this expected utility approach is not attempted here. In the next section the discussion above is collected to obtain the estimable supply equation for sawlogs.

5.3. Implicit supply equations

Collecting the comparative statics results of the present value maximizing forest owner from (5.9) to (5.11) and (5.13) gives the supply as an increasing function of the present stumpage price, forest owners time preference and the beginning of the period stock, and a decreasing function of the coming period stumpage price,

$$(5.23)\quad x_t^s = x^{s1}(\underset{+}{q_t}, \underset{-}{q_{t+1}}, \underset{+}{i_t}, \underset{+}{s_{t-1}}).$$

Signs of the partial derivatives are given under the variables. As has been already stated this model assumes, that all markets are perfect and that the forest property produces no other outputs than sawlogs.

The utility maximization in the present context means, not unrealistically, that there are imperfections in some of the markets. If the optimal plan is made only for one period and is renewed at the beginning of each period, following sawlog supply equation is obtained

$$(5.24)\quad x_t^s = x^{s2}(\underset{+}{q_t}, \underset{-}{m_t}, \underset{+}{s_{t-1}}).$$

Empirically, it is reasonable to assume that there are adjustment costs which show their effect in the coefficient of the lagged inventory. The supply equation (5.24) will be taken as the basis for an estimable supply equation. Because it is based on one period model the expectations are not considered explicitly. The present value maximizer's supply function above and the intertemporal utility maximizing approach (see also appendix 1) indicate that future values of exogenous variables also affect the present period supply. If the forest owner is a utility maximizer he is actually only interested in the expected change of the stumpage price (when there is no input costs to sawlog production).

The utility maximizer is, however, concerned both with expected price changes and with the actual price level, because the stumpage price brings utility through consumption of goods and services. The stumpage price level has therefore significance relative to the other present prices. However, besides the present period values, the future prices and incomes also affect the supply, although the intertemporal model could not define the signs of the effects.

The selection of the utility maximizing approach as the basis for empirical work is in the present contexts more justifiable than the present value maximizing approach. First, because of the imperfections in capital markets in Finland, there is no good empirical measure for the time preference of the forest owner (experimental estimations using interest rates in supply equation did not succeed). Further it is reasonable to assume that at least part of the forest owners have liquidity constraints, in which case the exogenous income and the actual stumpage level affect the supply.

Also, the experiments with expectation variables in empirical analysis failed. In spite of this, there is a good reason to believe that the present price used in the supply equation is, in practise, considered high or low by comparing it to other present prices but also to expected stumpage prices. This is the implication of the intertemporal utility maximizing model.

5.4. The estimable supply equation

The implicit supply function (4.24) shows that sawlog supply depends positively on the stumpage price and the existing standing timber stock and negatively on the exogenous income of the forest owner. The standing stock poses a problem in empirical short run analysis because it is almost impossible to measure and is reported in statistic only as an average figure over long time periods. Further more, it is not the physical timber stock, which should be used but the forest owners' subjective opinion of this stock. For this reason the dynamic demand formulation used by Houthakker and Taylor (1970), in the consumer demand study in the United States, will be adapted in order to derive the estimable supply equation.

This formulation has the advantage that the supply equation for sawlogs can be estimated without having standing stock explicitly in the supply function.

The implicit supply equation repeated from (4.24) now using capital letters for aggregate supply is

$$(5.24') \quad X_t^S = X(Q_t, M_t, S_{t-1})$$

and is approximated using a linear formulation. This approximation is similar to the one used by Houthakker and Taylor (op.cit, p. 10). The supply of sawlogs depends linearily on the stock and other exogenous variables of the model.[2] The equation for sawlog supply can therefore be written as follows

$$(5.25) \quad X_t^S = \Gamma_0 + \Gamma_1 \left(\frac{S_t + S_{t-1}}{2}\right) + \Gamma_2 Q_t + \Gamma_3 M_t + E_{5t}.$$

In (5.25) E_{5t} is the error term. To simplify the notation it is not considered while deriving the complete Houthakker-Taylor estimable equation (see Houthakker and and Taylor, 1970 p.23). Solving for $(S_t+S_{t-1})/2$ yields

$$(5.26) \quad \frac{S_t + S_{t-1}}{2} = \frac{1}{\Gamma_1} (X_t^S - \Gamma_0 - \Gamma_2 Q_t - \Gamma_3 M_t).$$

Approximating growth by a constant percentage of the standing volume and denoting this percentage by G (≥ 0) the standing stock identity becomes

$$(5.27) \quad \Delta S_t = S_t - S_{t-1} = G \left(\frac{S_t + S_{t-1}}{2}\right) - X_t.$$

Because G is a constant and not a function as in the models of representative forest owner, growth is better approximated by $G(S_t+S_{t-1})/2$ than by GS_{t-1} (op cit pp. 13-16). Substituting from (5.26) for $(S_t+S_{t-1})/2$ equation (5.27) is equivalent to

$$(5.28) \quad \Delta S_t = \frac{G}{\Gamma_1}(X_t - \Gamma_0 - \Gamma_2 Q_t - \Gamma_3 M_t) - X_t^S.$$

Using first differences of the variables equation (5.25) can be written as follows

$$(5.29) \quad X_t^S - X_{t-1}^S = \Gamma_1 \left(\frac{\Delta S_t}{2} + \frac{\Delta S_{t-1}}{2}\right) + \Gamma_2 (Q_t - Q_{t-1}) + \Gamma_3 (M_t - M_{t-1}).$$

Then, using equations (5.26) and (5.27), it follows from (5.28)

$$(5.30) \quad X_t^S - X_{t-1}^S = \Gamma_1 \left[\frac{G}{\Gamma_1} \left(\frac{X_t^S - \Gamma_0 - \Gamma_2 Q_t - \Gamma_3 M_t}{2}\right) - \frac{X_t^S}{2} + \frac{G}{\Gamma_1} \left(\frac{X_{t-1} - \Gamma_0 - \Gamma_2 Q_{t-1} - \Gamma_3 M_{t-1}}{2}\right) - \frac{X_{t-1}^S}{2} \right] + \Gamma_2 (Q_t - Q_{t-1}) + \Gamma_3 (M_t - M_{t-1}),$$

which, by transfering X_{t-1} to the right hand side, leads to the equation for supply

$$(5.31) \qquad X_t^S = \frac{-G\Gamma_0}{1 - (G-\Gamma_1)/2} + \frac{1 + (G-\Gamma_1)/2}{1 - (G-\Gamma_1)/2} X_{t-1}$$

$$+ \frac{\Gamma_2(1-G/2)}{1 - (G-\Gamma_2)/2} Q_t - \frac{\Gamma_2(1+G/2)}{1 - (G-\Gamma_1)/2} Q_{t-1}$$

$$+ \frac{\Gamma_3(1-G/2)}{1 - (G-\Gamma_1)/2} M_t - \frac{\Gamma_3(1+G/2)}{1 - (G-\Gamma_1)/2} M_{t-1}.$$

The coefficients of (5.31) describe the short term effects. The long term effects can be demonstrated by assuming that in equilibrium fellings (sawlog sales) equal growth so that

$$(5.32) \qquad X_t^* = GS_t^* .$$

Substituting into (5.25) results in

$$(5.33) \qquad X_t^* = \Gamma_0 + \frac{\Gamma_1}{G} X_t^* + \Gamma_2 Q_t + \Gamma_3 M_t ,$$

so that assuming $\Gamma_1 \neq G$,

$$(5.34) \qquad X_t^* = \frac{G\Gamma_0}{G-\Gamma_1} + \frac{G\Gamma_2}{G-\Gamma_1} Q_t + \frac{G\Gamma_3}{G-\Gamma_1} M_t .$$

The long run derivate of $X^*(t)$ with respect to $Q(t)$ is given by the coefficient of $Q(t)$ in (5.34) (Houthakker and Taylor, 1970 p. 12). The derivation of long run effects is mechanical and the results must be considered with care. Structural changes in the system may cause wrong interpretations of the long run effects if the structural variables in question are not included in the model. In particular, the shift variables of the short term supply curve may change over time. A variable with no importance ten years ago may become a central determinant of the long run supply ten years later. In principle, however, the formulation gives the possibility of separating the long and short term effects.

Using the fact that, e.g. $\hat{}M_t=(M_t-M_{t-1})+M_{t-1}=\hat{}M_t+M_{t-1}$, equation (5.31) leads to the estimable equation for sawlog supply

$$(5.35) \quad X_t^S = B_0 + B_1X_{t-1}^S + B_2\Delta Q_t + B_3Q_{t-1} + B_4\Delta M_t + B_5M_{t-1} + E_{6t},$$

where (5.36a) $B_0 = \dfrac{-G\,\Gamma_0}{1-(G-\Gamma_1)/2}$,

(5.36b) $B_1 = \dfrac{1+(G-\Gamma_1)/2}{1-(G-\Gamma_1)/2}$, (5.36c) $B_2 = \dfrac{\Gamma_2(1-G/2)}{1-(G-\Gamma_1)/2}$,

(5.36d) $B_3 = \dfrac{\Gamma_2 G}{1-(G-\Gamma_1)/2}$, (5.36e) $B_4 = \dfrac{\Gamma_3(1-G/2)}{1-(G-\Gamma_1)/2}$,

(5.36f) $B_5 = \dfrac{\Gamma_3 G}{1-(G-\Gamma_1)/2}$.

The parameters of equation (5.31) including the growth parameter of subjective estimate of the standing stock of sawlogs can be calculated from estimated coefficients, using equations (5.36a) to (5.36f), as follows

$$(5.37a) \quad G = \frac{B_3}{\frac{1}{2}B_3 + B_2} = \frac{B_5}{\frac{1}{2}B_5 + B_4}$$

$$(5.37b) \quad \Gamma_0 = \frac{2B_0(B_2+\frac{1}{2}B_3)}{B_3(B_1+1)}$$

$$(5.37c) \quad \Gamma_1 = \frac{2(1-B_1)}{1+B_1} + \frac{B_3}{\frac{1}{2}B_3 + B_2}$$

$$(5.37d) \qquad \Gamma_2 = \frac{2(\frac{1}{2}B_3 + B_2)}{1 + B_1}$$

$$(5.37e) \qquad \Gamma_3 = \frac{2(\frac{1}{2}B_5 + B_4)}{1 + B_1} .$$

From (5.37a) parameter G is over identified, its value can be calculated in two different ways. This over identification is likely to result into different values for G if no constraint is imposed in the estimation of the parameters in question. Estimation experiments showed that this complete Houthakker-Taylor equation could not be used in estimations and the form in which the final supply equation is estimated does not have this over identifying constraint.

The poor performance of the complete Houthakker-Taylor estimable equation is possibly due to randomness in the used short term data, so that the long term effects cannot be properly estimated. Also the study period is obviously too short for the long term effects to be adequately identified. The form in which the supply equation is estimated only takes into account the short term effects by assuming that, in the short term, growth is negligible. The final estimable equation and its derivation is reported in the next chapter, where the empirical results of the study are presented (section 6.2.1., p. 77).

The error term E_{5t} of the structural supply equation was not considered while deriving the complete estimable equation. Houthakker and Taylor show that the error term of equation (5.35), E_{6t}, which is a function of E_{5t}, G and Γ_1, is autocorrelated, if the error term of the structural supply equation, E_{5t}, is assumed not to be autocorrelated (Houthakker and Taylor 1970, p. 23). It is possible to calculate an "adjusted" D-W statistics for E_{5t}, when the estimates for G and Γ_1 have been obtained.

Without going into detailed discussion of the problem, it is only pointed out that values of D-W either near or below two indicate positive autocorrelation in E_{5t}(op cit, p. 35). Further more, as pointed out by Houthakker and Taylor, the autoregressive parameters of E_{6t} add a further constraint on G and Γ_1, which cannot be taken into account in estimations. (op cit). Because, the complete form of the estimable supply equation (5.35) will not be used, the problem is not considered in more detail. Besides, with the lagged endogenous variable in the model D-W statistics cannot, even without the above problem, be considered a reliable measure of autocorrelation (cf. Houthakker and Taylor, 1971 p. 35; Johnston, 1972 p. 312). For this reason also the Durbin's h-statistics will be reported, although it also directly indicates only the presence of autocorrelation of the estimated equation, but not the structural equation.

Notes on chapter 5:

1) I owe the inclusion of the stock identity as a constraint to the forest owner's maximizing problem and the interpretation of the equilibrium condition to Darius Adams.

2) Houthakker and Taylor derive the supply function using continuous time and convert it to discrete time for empirical purposes. No essentials are lost if the analysis is in discrete time. The only major difference arises in the treatment of the stock. In continuous time the dependence of the stock on the supply can be written using some positive constant parameter, G as follows GS(t). In discrete time, this is approximated by $G(S_t+S_{t-1})/2$, which is a better approximation of the continuous time relation than for example GS_{t-1} (op.cit, pp 13-15).

6. MODEL ESTIMATION

6.1. Aggregation and the data

The supply and demand functions of the representative forest owner and firm are assumed to be linear so that aggregation to the sectorial level is possible directly. Linear functional forms will be used in the estimations. It would also be possible to use a loglinear model in the stock adjustment and in the demand equation but because the Houthakker-Taylor supply equation must be estimated in linear form (Houthakker and Taylor, 1970 p. 8) the demand side of the model is also specified linearily. The assumptions of micro-relations required for the exact aggregation are restrictive and are not met in the above models for the representative firm and forest owner. The linearity of the demand and supply functions is therefore an approximation. However, in empirical analyses approximations like this are often unavoidable (cf. Maccini, 1977 p. 500).

To repeat, the beginning of the production period, t+1, raw material stock of the sawmill industry depends positively on the expected demand ($Z^e_{t,t+1}$), the expected sawnwood price ($P^e_{t,t+1}$), the lagged stocks (K_t) and the expected stumpage price, ($Q^e_{t,t+1}$). The stumpage price (Q_t) and the carrying cost of the stocks ($R^e_{t,t+1}$) have a negative effect upon it,

$$(6.1a)\quad K_{t+1}=K(\underset{+}{Z^e_{t,t+1}},\underset{+}{P^e_{t,t+1}},\underset{-}{Q_t},\underset{-}{R^e_{t,t+1}},\underset{+}{Q^e_{t,t+1}},\underset{+}{K_t}).$$

The supply of sawlogs from private nonindustrial forests on the other hand, is, according the one period model of the utility maximizing forest owner, an increasing function of stumpage price (Q_t) and stock of standing timber at the end of the previous period (S_{t-1}) and a decreasing function of the exogenous income (M_t).

$$(6.1b)\quad X_t^S = X^S(\underset{+}{Q_t}, \underset{-}{M_t}, \underset{+}{S_{t-1}}).$$

These two equations are the basic behavioral equations of the model. They indicate the type of data that is needed in the empirical analysis. The data are therefore presented here. Equation (6.1a) contains four unobservable variables and also their proxy variables are discussed . The expected demand for sawnwood ($Z^e_{t,t+1}$) during the coming period comes from explicit consideration of the uncertainty about sawnwood demand in export markets.

The other expectation variables are due to the periodization of the model of representative firm. The present period, when raw material is bought and the coming period when the production takes place, are considered explicitly. This relates the model to the real world decision making environment. The economic agent normally have only few exogenous variables known by certainty, affecting their decisions. Of course any periodization is bound to be, to a certain extent, arbitrary and in reality the periods continuously overlap.

Expectations in the stock equation (on the raw material demand side) will be handled using proxy variables, partly because more rigorous expectation formulas would require more observations than presently available partly because rough proxies already provide acceptable results. The expectations are considered static, so that the past and the future are alike. The expectation variables will be presented below when presenting the data.

Semiannual data was used in the estimations. The selection of a semiannual observation period was partly dictated by the available data, but it also seems that semiannual observation period is rather well suited to the seasonal pattern in sawlog and sawnwood markets (chapter 4, note 1, p. 35). Because of strong seasonality in the quantities, two term moving sums were used for seasonal adjustment. The use of seasonal dummies was tried and the parameter estimates in many cases did not vary much from the ones obtained from seasonally adjusted data. The use of seasonal dummies was abandoned because the seasonality is clearly changing during the estimation period and also because of the seemingly strong random variation in quantities (seasonal adjustment, cf. Wonnacot and Wonnacot, 1979 p. 201).

Stocks of sawlogs

The semiannual data for sawlog stocks were collected from the archives of the Central Association of the Finnish Forest Industries. This data covers roughly 70 percent of the stocks carried by the sawmill industry. Furthermore the coverage changes slightly from year to year, therefore, the data is not the best possible for studying short term development. At present, only aggregate stocks are used.[1)]

The present aggregation is common in empirical studies of stock adjustment. The term "stocks" is often replaced by "materials and goods in the process" to emphasize the fact that the materials and goods on the assembly line are also included (cf Lovell, 1962; Feldstein and Auerbach, 1976). In the present case, the production process takes such a short time that this part of the stocks is immaterial.

Sawnwood export sales

Data for export sales were collected from the archives of the Finnish Sawmill Owners' Association. The export sales, lagged by two periods are used to describe the expected demand of the sawmill industry firms. The two period lag comes from the strong seasonality in export sales (see figure A12 in appendix 5, p. 127).[2)]

Irvine (1981b p. 371), for example, used the same kind of proxy variable to describe the demand expectations. The expected sales of the following quarter were, in his model, the sales of the same quarter during previous year corrected with more recent information. This information was the fraction of present quarters sales of the sales during a quarter one year before. In the present case, this kind of expectation variable would look like

(6.2) $Z^{e}_{t,t+1} = Z_{t-2}(Z_{t-1}/Z(t-3))$,

where Z is now the export sales of sawnwood. Results of the estimations using this variable to describe the demand expectations proved to be inferior to those where the lagged value of export sales, without correction, was used.[3)]

Export prices

A large part of export sales are based on contracts, where the firm agrees on a delivery, which takes place during the coming shipments period, late autumn or at the beginning of the coming shipments year. Therefore contract prices would be the correct price series to be used here. However, average contract prices for sawnwood are not available. Also, the statistics of the contract prices of different sawnwood grades to different countries only begin in 1970 (in the archives of the Finnish Sawmill Owners' Association). The unit value of export shipments (value of sawnwood export divided by the quantity) (SITC 248, 2;

Foreign Trade, different years) with two periods lead is therefore used as a proxy-variable of the current periods export price. It takes from a quarter to one year from signing of the contract before the item leaves the country and enters the Foreign Trade statistics.

To give an idea of the relation between the average unit value of sawnwood and the contract prices, figure 4 shows monthly observations of the sawnwood export unit values and contract prices of pine to England (u/s and V).

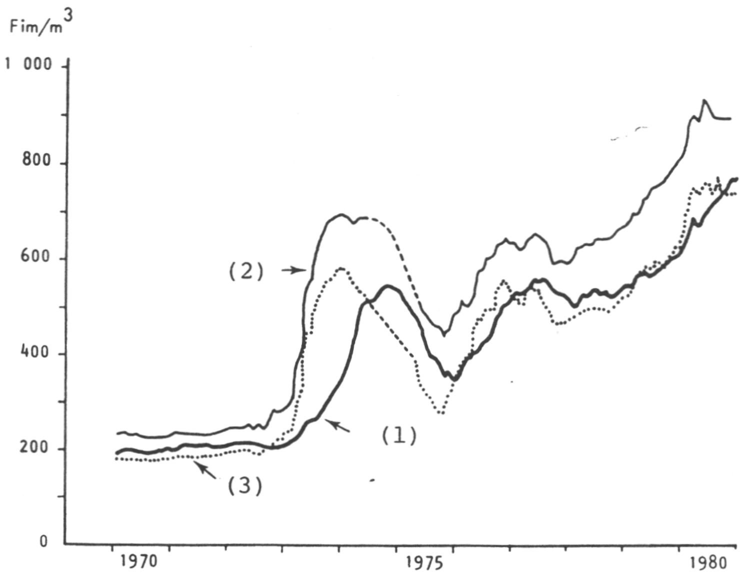


Figure 4. **The unit value of export** shipments (1) and **export contract prices of pine u/s** (2) and **V** (to England) (3), monthly observations from **1972 to 1980, seasonally unadjusted.**

The cross correlation functions calculated between export unit values and export contract prices (for current and deflated series) indicate a lag of from 7 to 10 months. This also fits the lag between sales and shipments, therefore the two periods lead in semiannual data is justified (Cross correlation functions calculated from the data of figure 4 are given in appendix 4, p. 126).

Export price expectations are also assumed static. Because prices do not experience seasonal fluctuations, current period prices can be used directly as the expected prices of coming period production, when the beginning-of-period raw material stock is decided. Besides, part of the coming period's shipments are sold already during the present semi-year, and therefore the contract price for part of the production is already known. The reason for talking about expected, rather than actual, values of the variables when explaining the stock demand for the sawlogs is the fact that at least part of the raw material must be bought before completing the export sales for a coming shipments period.

Sawlog purchases and stumpage prices

Stumpage prices (Q) and the sawlog purchases (from private nonindustrial forests, also referred to as sales of sawlogs from private nonindustrial forests) were collected from the basic data for forest taxation by sampling (archives of the Finnish Forest Research Institute, Mathematics Department). This was necessary because until 1979 only yearly observations of stumpage prices are reported in the Official Statistics of Finland and timber sales are not reported at all.

To obtain the semiannual time series of prices and quantities, a sampling method was used in order to economize on computation resources and time. The sampling, which was done with the help of Mathematics Department of the Finnish Forest Research Institute, is summarized in appendix 3, p. 122. These quantity and price series present the relative changes from period to period fairly reliably. The absolute level of the quantity traded, however, seems to bee downward biased in the 1960's, according to commercial fellings statistics.

Carrying costs of sawlog stocks

The stock equation (6.1a) has both expected stumpage price, ($Q^e_{t,t+1}$), and the expected carrying cost of stocks, ($R^e_{t,t+1}$), among the independent variables. In the analysis interest rate is used as a proxy for the carrying costs (assuming that other costs remain constant over time). Further more, static stumpage price change expectations are used instead of absolute second period expected stumpage price. These two are combined to a modified Hall - Jorgenson service cost of capital (cf. Irvine, 1981 p. 637). This is computed as a difference between the short term interest rate prevailing during the period t and the static expected stumpage inflation

(6.3) $RQ_t=(I_{t,t+1}-\hat{}Q_{t,t+1})$, where

RQ_t - service cost of capital

$I_{t,t+1}$ - short term interest rate prevailing at the beginning of period t+1,

$\hat{}Q_{t,t+1}$ - expected stumpage price inflation during period t+1.

Because the short term interest rate in Finland is regulated by the Bank of Finland, it is a poor measure of the rate of return from alternative investment (in this case the borrowing rate). The marginal rate of interest on the Central Bank debt is therefore used as a proxy of the short term interest rate. This variable was taken from the data of the Bank of Finland quarterly model for the Finnish Economy (BOF3) (Suomen Kansantalouden..., 1983 p. 241, see also Tarkka 1979). It, however, best describes the tightness of the capital markets, therefore it can be justified only by the poor performance of the borrowing rate, which seemingly does not have enough temporal variance.

The expected stumpage inflation is the actual inflation of the stumpage price during the present period, $\hat{Q}_{t,t+1} = (Q_t - Q_{t-1})/Q_{t-1} \times 100$.[4)]

Sawlog sales and stumpage prices

The supply equation partly contains the same variables as the stock equation. The explained variable is the sales (=purchases) of sawlogs, so that equality of supply and demand in each period is assumed. Above, purchases of sawlogs referred to the same thing because the matter was considered from the point of view of the sawmill industry. Here sawlog sales are denoted by X_t^S in order to distinguish from the demand (X_t^D). The data for sales of sawlogs and for stumpage prices have been already discussed above.

The forest owners' stumpage price expectations will not be considered explicitly in the estimations. However, the interpretation of the present price in the supply equation implicitly includes expected prices according theoretical considerations in chapter 6. For the present value maximizer (natural forests) the absolute price level was seen to be immaterial and therefore his decisions were based on expected price changes. Even though the one period model of the utility maximizer, which is used as the basis for empirical analysis does not include price expectations at all, present value maximizing approach and utility maximizing in intertemporal setting both suggest the inclusion of expectations. Therefore, even if the expected prices are not explicitly considered in the model they are likely to affect the supply through present prices, which are considered to be high or low partly with respect to what the prices are expected to be in the future.

Exogenous income

Exogenous income in the supply equation is measured by the after tax income of Finnish households (Suomen

Kansantalouden..., 1983, p. 147). The after tax income includes also those households, which have no forests. Therefore, it cannot be considered a good indicator of the exogenous income component of the theoretical model. However, it is considered better than, for example, value added from agriculture, which leaves about 40 per cent of the forest owners outside the analysis. For a more detailed discussion on measurement of exogenous income and its effect on timber supply, see Tervo (1981). He has experimented for example with different income variables from agriculture when estimating the stumpage sales (all timber assortments, annual data) from private nonindustrial forests. The coefficients of absolute income variables obtained contrary to a priori hypothesis positive signs. However, variables describing the profitability in agriculture behaved better, obtaining negative and in some cases statistically significant coefficients (op cit, pp. 104-106).

6.2. Estimation of the sawlog market model

6.2.1. Estimation method and the empirical model

The model was estimated using 2SLS (two stage least squares) and 3SLS (three stage least squares) methods and semiannual data. The longest feasible observation period was from 1962 to 1981, giving 40 observations. All prices, and the income variable in the supply equation, are deflated using whole sale price index (1977/2=100) (Statistical Year Book of Finland, different years). This was necessary because of the multicollinearity and autocorrelation of residuals when nominal prices were used.

The correction for autocorrelation in two stage estimations of the supply equation is made using the method suggested by Fair (1970). He has shown that consistent estimates in the case of serially correlated errors can be obtained only by including lagged dependent and independent variables in the instrument list when the model has lagged endogenous variable among independent variables.[5)]

The supply equation of the final model is estimated with only constant term, first differences of exogenous variables (Q_t and M_t) and lagged endogenous variable (X_{t-1}) as independent variables. This was due to the fact that including lagged values of exogenous variables made most estimated coefficients statistically nonsignificant. Also, the sizes of the coefficients became theoretically meaningless. Nonlinear estimation with an over identifying constraint in (5.38a, p. 64) failed to converge.

Leaving the lagged exogenous variables aside means that two parameters of the structural supply equation (5.25), p. 64, are lost, but it is still possible to compute the parameters of exogenous variables of the structural supply equation and the short term elasticities. This is seen by deriving the modification of the Houthakker-Taylor equation used in estimations (Houthakker and Taylor, 1970 p. 287).

Dropping the lagged endogenous variables from the estimable Houthakker-Taylor equation means that G, the relative growth is assumed to be zero, or so close to zero during the observation period compared to the other parameters to be estimated that the randomness of the data prevents its accurate estimation. Thinking of the short run supply, it actually seems natural that the growth, which is very small compared to the stock or even compared to the discrete amounts sold in each observation period, does not markedly affect the sales decisions. This stresses the asset feature of the standing timber stock so that the short term price changes have a dominant importance on the short term supply decisions. When growth is zero, the stock identity from (5.27), p. 62) becomes

(5.27') $S_t - S_{t-1} = -X_t^S.$

To repeate, structural supply equation from (5.25) is

(5.25) $$X_t^S = \Gamma_0 + \Gamma_1 \left(\frac{S_t+S_{t-1}}{2}\right) + \Gamma_2 Q_t + \Gamma_3 M_t + E_{5t}.$$

Stock identity (5.27') does not work in the long run because the stock would be soon depleted. Using the linear structural supply relation (5.25), equation (5.30), giving the first difference of the sales, is now

(5.30') $$X_t^S - X_{t-1}^S = \Gamma_1 \left(-\frac{X_t}{2} - \frac{X_{t-1}}{2}\right) + \Gamma_2 \Delta Q_t + \Gamma_3 \Delta M_t.$$

This finally leads to the estimable supply equation by solving for X_t^S

$$X_t^S = \frac{1 - \Gamma_1/2}{1 + \Gamma_1/2} X_{t-1}^S + \frac{\Gamma_2}{1 + \Gamma_1/2} \Delta Q_t + \frac{\Gamma_3}{1 + \Gamma_1/2} \Delta M_t + E_{7t},$$

so that

(5.35') $$X_t^S = B_1 X_{t-1}^S + B_2 \Delta Q_t + B_4 \Delta M_t + E_{7t}.$$

The parameters of the structural supply equation (except for the constant term) can be calculated from the estimated parameters of (5.35') as follows

(5.37c') $$\Gamma_1 = \frac{2(1-B_1)}{(1+B_1)}$$

(5.37d') $$\Gamma_2 = \frac{2B_2}{1 + B_1}$$

(5.37e') $$\Gamma_3 = \frac{2B_4}{1 + B_1}.$$

When reporting the estimation results, (5.37c') -(5.37e') will be used to calculate the parameters of the structural sawlog supply equation. Although the value of the constant term cannot be computed, it still is in the structural supply equation. Equation (5.35') shows that the constant term should not be included in estimable equation. Experiments indicated that the statistical performance of the equation was inferior without the constant term than if the constant term is included. Therefore the constant term was included to the final model, even realizing the theoretical inconsistency. The absolute values of the coefficients and elasticities are not significantly affected by the inclusion.

The supply elasticities are computed using the structural parameters and means of the variables in question. The error term E_{7t} of the estimable supply equation is the following function of the error term of the structural supply equation (5.25)

$$E_{7t} = \frac{\Delta E_{5t}}{1 + \Gamma_1/2}$$

and is obviously autocorrelated. Therefore the correction for serial correlation in estimations is necessary.

The stock equation and the sawlog supply equation represent two different sides of the markets. The stumpage price is not exogenous to the model. In order to avoid simultaneous equation bias this endogenity must be taken into account in the estimations (cf Koutsoyiannis, 1977 p. 331). This fact is often not explicitly considered in the inventory literature.

Some problems in the estimations are, at this juncture, discussed with the help of the complete sawlog market model. The stock adjustment equation (4.26), p. 34, with the service cost of capital replacing expected stumpage price and carrying cost of stocks, is used on the demand side. This form of the simultaneous sawlog market model shows the exogenous variables, which are used in the instrument list when estimating the stock adjustment equation. It also explicitly shows the role of stock adjustment in the model, which is not so easy to see when the more conventional supply-demand formulation is used.

With the equilibrium condition the model contains three equations and three endogenous variables, beginning of t+1 period stock, K_{t+1}, supply of sawlogs from private non industrial forests, X_t^S, and the stumpage price, Q_t.

(6.4a) $$K_{t+1} = \Phi_0 + \Phi_1 Z^e_{t,t+1} + \Phi_2 P^e_{t,t+1} + \Phi_3 Q_t + \Phi_6 RQ_t + (1-\delta)K_t + E_{3t}$$

(6.4b) $$X_t^S = B_0 + B_1 X_{t-1}^S + B_2 \Delta Q_t + B_4 \Delta M_t + E_{7t}$$

(6.4c) $$X_t^{TS} = X_t^S + X_t^{OS} = K_{t+1} - K_t + \bar{U}_t = X_t^D .$$

The demand is, by definition the change in the stock during the period added by the consumption of raw material in production ($\bar{U}_t$, predetermined;- see below). This is used when writing the equilibrium condition (6.4c). Unintended stock variations are included in the error term. The total supply X_t^{TS} is the sum of the supply from private non industrial forests (X_t^S) and other supply (X_t^{OS}), which is exogenous to the model.

A problem is that there is no semiannual data available concerning the exogenous supply of sawlogs from other sources than private nonindustrial forests (X_t^{OS}). This variable can, in principle, be calculated as a residual from the equilibrium condition. Because of the different coverage of the stock, production and sawlogs sales data, the computation cannot be made with the present data. For a discussion of the importance of the supply of timber from other forest owner groups, which is about 20% of the total consumption of roundwood, see Tervo (1978; 1981).

The endogenous price variable does not enter the supply and demand sides of the model in the same way. The instruments in the stock (and later in the demand) equation are explaining the current stumpage price, but in the supply equation the current stumpage price change is explained. This poses no problem because the variation in $\hat{-}Q_t=Q_t-Q_{t-1}$ is caused by changes in Q_t while Q_{t-1} is predetermined. Disregarding the multicollinearity problems, in fact, the supply equation could be estimated using Q_{t-1} and Q_t as separate variables.

The production of the present period does not enter the stock equations at all. From the theoretical model we see that this is because the adjustment costs are considered to be a function of the changes in the raw material stock level.

The stumpage price agreement dummy (D3) was added to all estimated equations of the model. This variable is zero until the second half of 1978, when for the first time an agreement concerning the recommended sawlog stumpage price for the whole country was reached by the Forestry Council of the Central Union of Agricultural Producers and the Central Association of the Finnish Forest Industries. During the felling season 1979/80 no agreement for the whole country existed. In spite of this also for this felling season the value of the dummy variable is one, because there seems to be a structural change in the markets from 1978 onwards, unexplained by other exogenous variables of the model.

6.2.2. Raw material stock adjustment

The stock equation was estimated using the exogenous variables of the complete model as instruments (including lagged stumpage price). The estimated results of equation (6.4a) are the following:

$$(6.4a)\ \hat{K}_{t+1} = -2781.94 - 13.53Q_t + 10.36P^e_{t,t+1} + 0.36Z^e_{t,t+1}$$
$$(1.05)(1.43)\quad (4.36)\quad\quad (1.32)$$
$$-71.42RQ_t + 0.73K_t + 1889.43D3_t,$$
$$(2.43)\ (10.19)\quad\quad (2.27)$$

$\bar{R}^2=0.94$ D-W=1.87; h=0.46; n=40; $\delta=0.27$

Variable	Elasticities of stock level short run	"long run"
Q_t	-0.15	-0.56
$P^e_{t,t+1}$	0.53	1.96
RQ_t	-0.06	-0.22

At this juncture, the estimation results of the complete model are not presented, because the supply equation is the same as the one that will be estimated in the next section. There the stock equation is replaced by the demand equation to produce a conventional simultaneous market model for sawlogs.

Statistically the stock equation behaves rather well and the signs of the parameters are those expected. The adjusted coefficient of determination ($\bar{R}^2$) is 0.94 and D-W- and Durbin's h-statistics (critical point 1.645) do not indicate autocorrelation of the residuals. The coefficients of the expected export price, user cost of capital, lagged stock and the dummy variable are statistically significant. (Critical 5 per cent and 1 per cent points of Student's t distribution with 33 degrees of freedom are 2.042 and 2.750 respectively.) The coefficients of the stumpage price and the expected demand are significant only at 20 per cent risk level (relevant critical point 1.310).

Adjustment of the stocks to the target level is slow. Only

0.27 percentage of the gap between desired and the actual inventory level is corrected during the period. Autocorrelation could not be detected (ρ did not obtain statistically significant estimate when Fair's method was used). It is unlikely, therefore, that the small value of δ is caused by the autocorrelation. This result contradicts the findings of many earlier studies (cf. Feldstein and Auerbach, 1976), which report in many cases very fast stock adjustment. Because of the level of aggregation and the relatively large sawlog stocks compared to the raw material used in production during observation period, the slow adjustment in the present case seems justified. The aggregated stock contains all raw material from stump to the factory and cover the raw material input of half to one year's production.

Both stumpage and final good prices affect the beginning of the period t+1 stocks, although stumpage price only at 20 percentage risk level. The elasticities of the stocks with respect to stumpage price and sawnwood price are both smaller than one in absolute terms. Elasticities are calculated using estimated coefficients and means of the variables in question. According to the model of the representative firm, $P^e_{t,t+1}$ is the price that the firm expects to get from sells the production of the period t+1. In estimations the unit value of export sales with two period lead was used. The variable is therefore a "double" proxy. The unit value is used as a proxy of the contract price of the present period (t), which is assumed to present the expected sawnwood price of production of the coming period.

Also, the coefficient of the cost of capital turned out to be statistically significant at the 5 per cent risk level, and negative as suggested by the theory. The absolute value of the elasticity is however very small. The stock adjustment equation behaved very much the same way when only the static stumpage price change expectation was in the equation. The coefficient of the expected stumpage price change was positive and statistically significant, although here also the elasticity computed from the average change over the period was very small. Leaving both user cost of capital and stumpage price change expectation out of the equation, made the coefficients of present stumpage price and expected demand statistically significant at 5 per cent risk level. This indicates a problem of multicollinearity, when these variables are in the equation.

The "long run" elasticities of the stocks are also presented above. They are obtained by dividing the short term elasticities by the stock adjustment coefficient (δ). These results must be considered with care. First, the model of the representative firm in chapter 4 cannot explain the long run behaviour at all if the "long run" is interpreted so that the production capacity can vary. What the "long run" means in the present model is the absence of the stock and production adjustment costs, but with uncertainty remaining in the expected final good demand.[6)]

The "long run" elasticities are therefore better referred to as the elasticities of the desired stock with respect to the exogenous variables of the model. It is natural that the stocks would fluctuate much more if the adjustment costs were absent. This is reflected by "long run" elasticities, which are about four times the short run elasticities. Actual and fitted values of the stock equation are plotted in figure 5.

Estimating the stock equation for the period 1962/1-1978/1, the period without recommended price agreements, increases the t-values of the coefficients of stumpage prices and expected demand only slightly. The t-value of the coefficient of the user cost of capital decreases. Except for the slightly larger stumpage price elasticity (-.21), the absolute sizes of the coefficients remain approximately

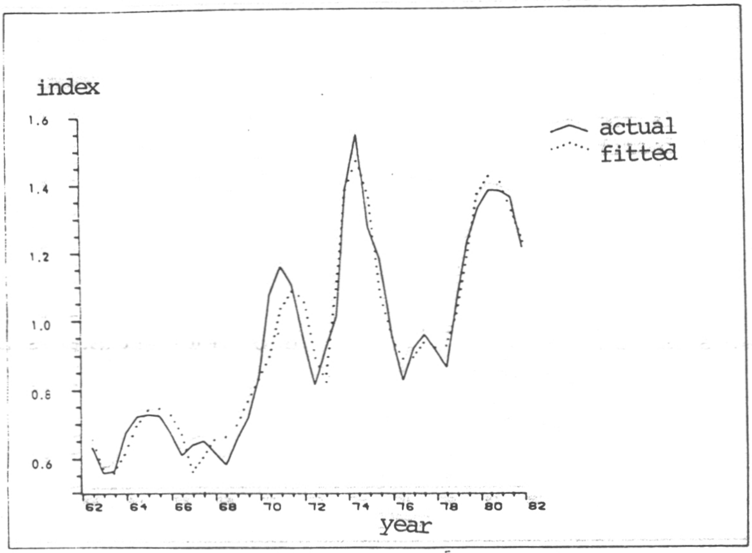


Figure 5. Actual and fitted values of the stock adjustment equation , 1962-1981.

the same as for the whole study period.

6.2.3. Simultaneous sawlog market model

Using the demand equation (4.27), the sawlog market model can be estimated in the following form

(6.5a) $$X_t^D = \Pi_0 + \Pi_1 Z^e_{t,t+1} + \Pi_2 P^e_{t,t+1} + \Pi_3 Q_t + \Pi_6 RQ_t + \Pi_7(K_t + \bar{U}_t) + E_{4t}$$

(6.5b) $$X_t^S = B_0 + B_1 X^S_{t-1} + B_2 \Delta Q_t + B_4 \Delta M_t + E_{7t}$$

(6.5c) $$X^D - X_t^S = X_t^{OS}.$$

Neither user cost of capital nor the static expectation of stumpage price change in the demand equation obtained statistically significant parameter estimates. Because these variables also created multicollinearity problems they were left out from final model.

The model is over identified and therefore 2SLS and 3SLS methods are applicable (cf. Koutsoyiannis, 1977). The problem of the residual supply from other forest owner groups (X_t^{OS}), discussed above, remains. However, the predetermined consumption of the raw material ($\bar{U}_t$) in productions is explicitly included in the demand equation. Consumption of raw material was obtained by multiplying the production (Bulletin of Statistics, different years) during the period by 2.2, the inverse of the coefficient of proportionality from the production function ($1/\alpha$).

Because $\bar{U}_t$ enters the demand equation from the stock identity, its coefficient should, by definition, be one. This restriction is not likely to hold rigidly because of estimation problems and because of the different coverage of the stock, production and the sales data. Inclusion of the variable $\bar{U}_t$ directly to the estimable equation creates a problem of multicollinearity. For this reason, when lagged stock and consumption of raw material were both included in the demand equation as separate variables, neither obtained a statistically significant coefficient. It also turned out that using a priori information when creating a new variable

(6.6) $(\delta KU)_t = \bar{U}_t - \delta K_t$,

made the residuals severely autocorrelated. The value of δ was taken from the estimated stock equation (6.4a') above. Again the coefficient of ($\delta KU)_t$ did not become statistically significant.

Therefore, instead of using the prior information in the estimation, the lagged stock and the consumption of the raw material during the period were added and the sum was used as an independent variable (denoted by $(K_t+\bar{U}_t)$).

Statistically, this formulation is less problematic than the stock equation above. When the explained variable is the sawlog sales during the period, the equation does not contain a lagged endogenous variable.

The estimated results of model (6.5) are presented in table 1. Both two stage and three stage least squares results are reported. The three stage estimation is considered more reliable here, because the residuals of the supply and demand equations from two stage estimation were correlated (correlation between the residuals was 0.41). The supply equation is estimated using correction for serial correlation.[7)] The two stage least squares results are statistically acceptable, disregarding the low coefficient of determination of the supply equation and that D-W statistics in both equations remain in the undetermined area. Furthermore, Durbins h-statistics indicates autocorrelation of residuals in supply equation. In the demand equation correction for serial correlation was also tried but the coefficient of serial correlation did not obtain a statistically significant parameter estimate.

The three stage results must be also considered satisfactory in the case of the demand equation. The t-values are even higher than those of the two stage least squares estimates. Unfortunately, the t-values in the supply equation decrease except for the the first difference of the stumpage price. The coefficient of determination also decreases in the supply equation considerably. The signs of the coefficients are those predicted by the theoretical model.

The short run sawlog demand elasticities with respect to stumpage price and sawnwood export price are -0.9 and 1.3 respectively. (Structural parameters of the supply equation and elasticities of demand and supply are calculated from the three stage least squares estimates.) The elasticities of the raw material demand with respect to the final good prices and stumpage prices are higher than the elasticities of the raw material stocks. This indicates that there is a

Table 1. Two stage and three stage least squares results of sawlog market model (relevant critical points of Student's t distribution at 5 per cent and 1 per cent risk level are 2.042 and 2.750 respectively).8)

Independent variables	2SLS Demand	2SLS Supply	3SLS Demand	3SLS Supply
C	-6179.89	7142.98	-5502.40	8073.05
	(3.46)	(4.79)	(3.46)	(5.59)
Q_t	-41.55		-45.50	
	(4.11)		(5.17)	
$P^e_{t,t+1}$	14.49		14.28	
	(6.94)		(7.66)	
$Z^e_{t,t+1}$	1.33		1.31	
	(6.21)		(7.04)	
K_t+U_t	0.16		0.18	
	(2.56)		(3.20)	
$\hat{Q}_t$		83.01		94.78
		(5.10)		(6.18)
$\hat{M}_t$		-0.14		-0.08
		(1.64)		(1.08)
X_{t-1}		0.34		0.21
		(2.41)		(1.52)
D3	1491.03	6308.36	1344.15	5629.82
	(1.53)	(2.23)	(1.55)	(2.17)
$\bar{R}^2$	0.84	0.47	0.83	0.36
D-W	1.68	1.55	1.70	1.45
h	-	3.05	-	3.45
ρ	-	0.54	-	0.54

Structural parameters of the supply equation:9)
(G=0, Γ_0=not determined) Γ_1=1.51 , Γ_2=156.67, Γ_3=-0.13.

Elasticities:

Variable	Demand short run	Demand "long run"	Supply
Stumpage price	-0.91	-3.37	3.13
Sawnwood export price	1.32	4.88	-
Income	-	-	-0.44

fairly large minimum stock above which the desired stock changes fluctuate. Only if the stocks were allowed to decrease to zero at the end of every production period, would the elasticities become exactly the same for the beginning-of-period stock and for the demand.

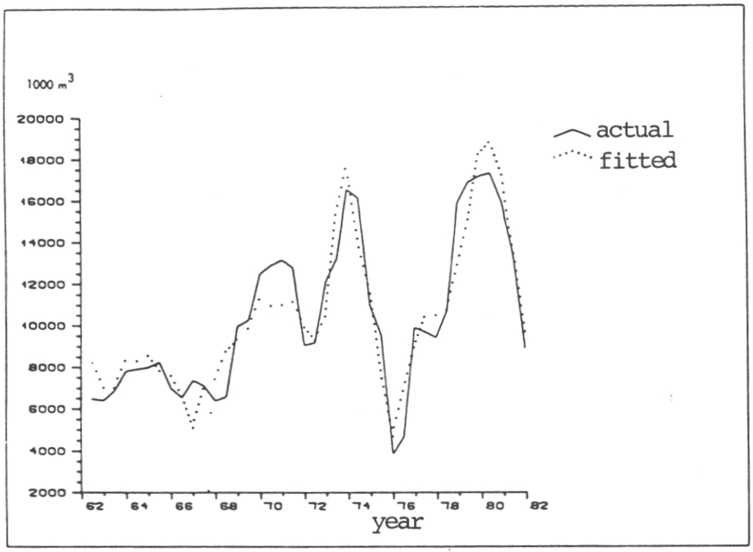
Using the above estimated value of δ=.27, the stock adjustment parameter, and the means of stocks and consumption of raw material in production, the coefficient of $\bar{U}_t$ is 0.81. (This is calculated by substituting means of K_t, $\bar{U}_t$ and $(K_t+\bar{U}_t)$ and estimated values of δ and Π_6 in $-\delta K_t + \psi\bar{U}_t = \Pi_6(K_t+\bar{U}_t)$ and solving for ψ.) The coefficient of raw material consumption is therefore smaller than unity, which probably is caused by the different coverage of production, stocks and sales data.

From the results, it is impossible to say to what extent the ex post decisions to correct the production level according to the realized forecast errors affect the demand. These corrective measures mean that the consumption of wood is not fully exogenous, so that the semiyear is already long enough to allow adjustments in production. This is actually assumed in the theoretical model, although the ex post decisions are not explicitely considered.

According to the results, both stumpage and sawnwood prices affect the demand for sawlogs. With respect to the stumpage price, the demand is inelastic, with respect to the expected sawnwood price it is elastic. In particular, the result concerning elastic sawlog demand with respect to the sawnwood price must be considered with care. In the sawnwood markets, the average unit value is not actually a very good indicator of the ruling price level. This is because the quality of sawnwood varies considerably over the business cycles. Therefore even if the price level seems to be fluctuating relatively little, the actual price changes may be larger because of the quality changes inside different sawnwood grades. Therefore, the estimated elasticity with respect to the final good price may be an overestimate.

The statistical performance of the supply equation is not very good. Adjusted coefficient of determination is only 0.35 in the three stage least squares estimation, and only the coefficients of the first difference of the stumpage price and price agreement dummy are clearly statistically

(a)



(b)

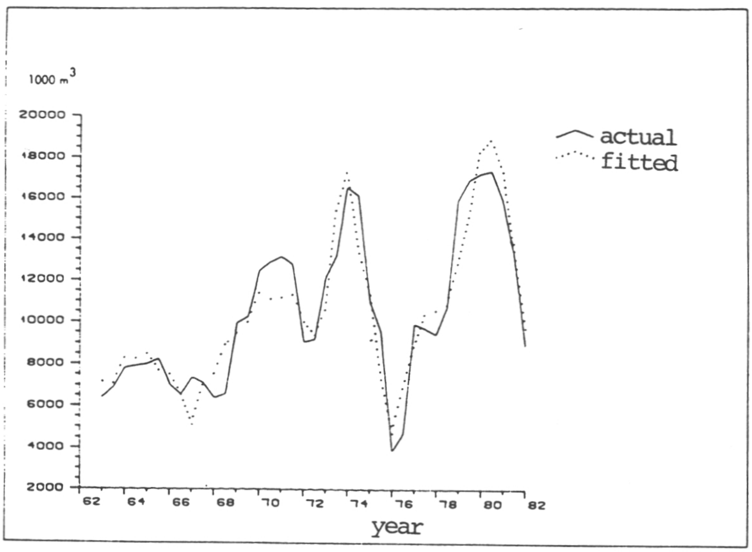


Figure 6. Actual and fitted values of the demand equation, (a) 2SLS, (b) 3SLS, 1962-1981.

significant. In the two stage estimation the coefficients lagged endogenous variable and of the first difference of the exogenous income are also statistically significant, although the latter only at 20 per cent risk level. Furthermore, the equation is autocorrelated so that the t-values are likely to be overestimated.

Additional confidence is given to the results by the fact that the absolute values of the coefficients remain about the same in two stage least squares and three stage least squares estimations. The parameters of the structural supply equation (5.25) (p. 76) have been computed using equations (5.38c') to (5.38e') (p. 77). According to the three stage least squares results the elasticity of supply is fairly high (3.1). The two stage least squares method gives a lower price elasticity (2.5). In both cases, however, the supply is clearly price elastic.

The elasticities obtained are higher than those of earlier studies. For example Korpinen (1981) reported a short run supply elasticity of sawlogs to be 1.6 and according to Brännlund et al. (1983) the corresponding figure in Sweden is 0.6. These are not, however, directly comparable to the elasticity estimate reported in table 1, because both studies quoted use commercial fellings to describe supply and demand, not sales. Furthermore, the estimation periods in these studies are longer and annual data is used. Finally, Korpinen used nominal prices.

At least in Finland, the fluctuations in sawlogs sales are on the average larger than in commercial fellings (Kuuluvainen, 1982 p. 8) and also the timing of the turning points of sawlog sales is different to commercial fellings (Kuuluvainen et al 1981, p. 260). For this reason, the model was also estimated using commercial fellings with a one period lead as the explained variable. The one period lead comes from the technical delay between commercial fellings and the actual sales. The length of the lead (semiyear) is supported by the cross correlation function between these two variables (op cit).

The estimation results (appendix 6, table A2, p. 128) indicate that the picture of the short term behaviour of the sawlog market is different if commercial fellings is used as the quantity series. All price elasticities obtain smaller absolute values. The greatest difference is between the supply elasticities. Sales gave the stumpage price elasticity of supply which is above 3. When commercial fellings are used this elasticity is much smaller (1.7).

When the model was estimated for the period 1962/1-1978/1 (the period without recommended price agreements), the elasticity of supply in 3SLS estimation decreased to 2.5 and the coefficient of exogenous income obtained positive statistically nonsignificant coefficient. Otherwise the results remained about the same.

Because the seasonal adjustment, while creating problems in estimations may affect the parameter estimates, the model was also estimated using annual data (by felling seasons: II/I). Sawlog stocks of the industry are in this case summer stocks. The results are reported in appendix 9 (p. 134) and give very little reason to change the qualitative conclusions of the model. The only major differences are the decrease of the elasticity of supply with respect to the stumpage price from 3.1 above to 1.83 and the increase of the adjusted coefficient of determination of the supply equation to 0.60. This indicates that specially the results concerning the short run elasticity of supply with respect to stumpage price must be considered tentative.

6.2.4. Stumpage price equations

Table 2 reports the estimated results of the stumpage equations where all the exogenous variables of the sawlog market model have been used as independent variables. Although the model (6.5) was estimated using real prices, nominal price equations are of interest because they lead to

(a)

(b)

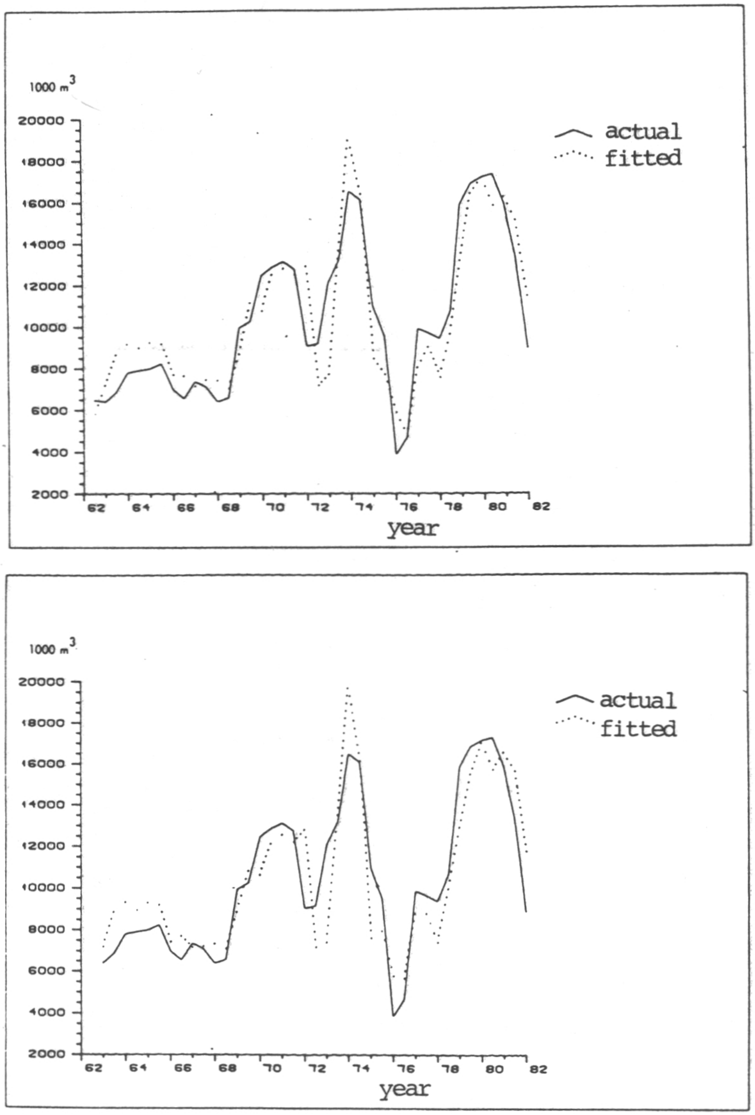


Figure 7. Actual and fitted values of the supply equation (a) 2SLS, (b) 3SLS, 1962-1981.

slightly different picture of the nature of the markets than deflated prices (for detailed discussion, see Kanniainen and Kuuluvainen, 1984).

As expected, D-W and Durbin's h-statistics indicate positive

Table 2. Estimated results of stumpage price equations. Equations in columns 1 and 3 contain all reduced form variables of sawlog market model. In columns 2 and 4, models with only constant term, lagged price and a dummy variable (stumpage price agreement dummy D3) as independent variables are reported.

Explained variable: stumpage price

Independent variables	Nominal prices Reduced form 1	Lagged price 2	Real prices Reduced form 3	lagged price 4
C	-49.024	3.962	-77.474	37.169
	(3.09)	(0.68)	(2.86)	(1.84)
$Z^e_{t,t+1}$	0.007		0.010	
	(2.84)		(3.60)	
$P^e_{t,t+1}$	0.039		0.082	
	(2.81)		(3.81)	
Q_{t-1}	0.80	1.004	0.74	0.82
	(8.49)	(21.21)	(8.29)	(8.67)
$\hat{-}M_t$	0.0001		0.77	
	(0.17)		(0.06)	
(K_t+U_t)	0.001		0.001	
	(1.23)		(0.65)	
X_{t-1}	-0.002		-0.002	
	(1.12)		(0.85)	
D3	-7.81	13.481	-13.72	2.49
	(0.92)	(1.42)	(0.98)	(0.26)
$\bar{R}^2$	0.98	0.96	0.84	0.65
D-W	1.23	1.08	1.25	1.00
h	2.39	3.04	3.02	3.91

autocorrelation with seasonally adjusted data. Correction for serial correlation was not, however, considered necessary because it only increased the D-W statistics without affecting the sizes of the estimated coefficients or their statistical significance. The t-values of the reported equations are, however, higher than if the correction for serial correlation is made or if the original (seasonally unadjusted) data is used. The number of statistically significant coefficients remains the same.

One way to test the price formation in the markets (in addition to the auto- and partial autocorrelation tests in section 3.1 and appendix 2, p. 118) is to see how well previous period prices predict present prices. If the information in the market is perfect, the present price should contain all information required to forecast future prices (cf. Sargent 1976, p. 214). Even in this case, it is possible to forecast future prices using all exogenous and predetermined variables of the model. However, if the present price is included in the equation, other variables are of no help in forecasting.

In columns 2 and 4, the equations containing only lagged price, constant term and price agreement dummy as the independent variables, are presented. In the markets with perfect information, the coefficient of lagged price is theoretically one, the constant term zero and the error term is white noise. It turns out that nominal prices could rather well be explained using only lagged price (table 2, column 2). In the nominal price equation, coefficient of lagged price is close to one and both the constant term and the dummy variable obtain statistically nonsignificant coefficients. The adjusted coefficient of determination is, however, slightly larger in the corresponding equation, where all exogenous variables of the sawlog market model have been used (table 2, column 1). Also the coefficients of expected sawnwood price ($P^e_{t,t+1}$) and expected demand ($Z^e_{t,t+1}$) are statistically significant, which contradicts the assumption of perfect price flexibility.

When prices are deflated the coefficient of determination decreases clearly and the coefficients of lagged price are smaller than unity. Also, the constant term is different from zero. This may indicate that agents in the markets have better picture of the future development of nominal prices than of real prices (see also auto- and partial autocorrelation functions in appendix 2). This is a plausible result, because forecasting the development of real prices requires more information than forecasting current prices. The autocorrelation and partial autocorrelation functions indicate perfect price flexibility in sawlog market, but the results of the regression equations are somewhat contradictory.

In appendix 8 (table A3, p. 132), the price change equation corresponding to the reduced form of the sawlog market model (6.5) is also reported. The adjusted coefficient of determination of this equation is somewhat smaller than that of the corresponding price level equation in table 2, column 3. In both cases the same variables obtain statistically significant coefficients. According to the plots of actual and fitted values of price equations in appendix 7 (figures A15-A18, pp. 130,131) the price equations are inferior to the quantity equations in forecasting the turning points. This is due to the strong effect of the lagged endogenous variable in the price equations. In this respect, the price change equation behaves better (figure A19, p. 133). It is for example able to explain the price movements of the mid-1970's rather well.

The reduced form equation for sawlog sales is also reported in appendix 8 (table A3, p. 132). All coefficients except that of the sum of lagged stock and consumption of raw material, are statistically significant. Coefficient of determination is 0.90. This equation forecasts the turning points in sawlog sales well (figure A20, p. 133).

While the present study is not concerned with forecasting, the reduced form equations could well serve as the basis for a short term forecasting model for sawlog sales and/or prices.

Notes on chapter 6.

1) Aggregate stocks include all the wood which has been purchased but has not yet entered production (=standing and felled timber in the forests, stocks at roadsides and at factories).

2) The export sales usually peak before Christmas. For example, during 1964 to 1969 and 1970 to 1976 about 40 per cent of the coming shipments period's production is sold during the last quarter of the previous year (Lattu, 1977 p. 18). In the present study, no difference is made according to which year's shipments the sales are addressed. Part of the sales during the last half of the year are therefore going to current year's shipments while part is going to the coming year's shipments.

3) A problem of the static export demand expectation is that it may also describe the liquidity of the firms. The income from the sales of the previous shipments period of course affects firms possibilities in acquiring raw material for the coming shipments season.

4) The theoretical model actually stresses the expected stumpage price change, not the coming period stumpage level. This is seen from equation (4.22) (p. 29).

5) If the model to be estimated is (capital letters are here used to denote matrixes and vectors)

$AY+BX=U$ and
$U=RU_{-1}+E$

with standard assumptions of E, then the estimation of the first equation of the system,

$y_1=-A_1Y_1-B_1X_1+u_1$

requires y_{-1}, $Y_{1_{-1}}$, X_1 and $X_{1_{-1}}$ in the instrument list, where $Y_{1_{-1}}$ includes all lagged dependent and $X_{1_{-1}}$ all lagged independent variables.
The correction serial correlation using Fair's method was used only in the two stage least squares estimations (which therefore might be better referred to as structurally ordered instrumental variables method (Wonnacot & Wonnacot, 1979 p. 295. In the three stage estimation, a standard correction for serial correlation was used to ensure that the instrument list in demand and supply equations was exactly the same (see note 7 below).

6) It is normally assumed that the uncertainty disappears from the model in the long run. In the present case, the absence of the uncertainty makes the solution to the profit maximization problem of the firm uninteresting. If there is no uncertainty, the input demand of the firm can be determined using the derivate property of the cost function after the desired production level has been decided by some other method (cf Varian, 1978 p. 31). The input demand in that case is the product of the coefficient of proportionality and the demand of sawnwood, known now with certainty. Therefore only when $\lambda \geq 0$, $K_{t+1} \neq (1/\alpha)Z^e_{t,t+1}$, i.e. in presence of uncertainty, the beginning of the production period stock deviates from

the level of simple accelerator of coming period demand.

7) Because the nonlinear estimation algorithm employed does not allow correction for serial correlation, the supply equation was first estimated with the linear two stage least squares method in order to obtain an estimate for , the serial correlation coefficient. This coefficient was then used to transform the data according the following equation (cf. Wonnacot & Wonnacot, 1979 p. 216)

$$Y_t - \rho Y_{t-1} = \beta_0 (1-\rho) + \beta_1 (X_t - \rho X_{t-1}) + (e_t - \rho e_{t-1}),$$

where the error term has the properties required by ordinary least squares. When the equations are linear in parameters also the nonlinear algorithm produces conventional linear two stage least squares estimates. The nonlinear algorithm was used, however, because it served as the initial two stages of the nonlinear 3SLS method. In the three stage estimation the two stage estimates are used to form an estimate of the residual covariance matrix. This matrix is then used as weighting matrix in the generalized least squares estimation of the third stage in order to reduce the correlation of the residuals of the equations of the model.

8) The results reported in table 1 are obtained using real prices and real exogenous income of the forest owners. The model was also estimated using nominal values for prices and income, but because of multicollinearity problems nominal price estimations are considered less reliable than those reported in table 1. However, the qualitative conclusions of the model are not seriously affected by the nominal price estimations. The major differences compared to the results of table 1 are the decrease of the supply elasticity with respect to the stumpage price to 2.4 and the somewhat surprising increase of the supply elasticity with respect to exogenous income in absolute terms. Using nominal prices the income elasticity becomes as high as -2.0 and coefficient of the first difference of the income variable in the estimated supply equation becomes statistically "almost" significant (with t-value 1.63).

9) Rigorous interpretation of the coefficient of stock is not attempted because of the tentative nature of the supply equation. It is very difficult to say in the present context whether its size is reasonable. However the positive sign indicates that stock of sawlogs and sales move into the same direction as one would expect.

7. SUMMARY AND DISCUSSION

The present investigation concerns the short term sawlog market in Finland. A selected literature review in chapter 2 is followed by discussion on the nature of sawlog market and stock holding motives in chapter 3. The basic assumptions of the work (chapter 3) are price flexible sawlog market and fixprice sawnwood markets during the study period (1960-1981). The nature of the markets is reflected in the motives for holding stocks. It is argued that the sawmill industry is holding raw material stocks (sawnwood stocks are not dealt with) to cover technical delays in raw material procurement, to buffer fluctuating stochastic sawnwood demand and to anticipate prices. The assumption of flexible price sawlog market is supported by auto- and partial autocorrelation tests. In contrast to the sawlog market, price adjustment in the export sawnwood markets seems to be rigid.

In chapter 4, the sawlog demand function is derived for expected profit maximizing sawmill industry firm. The firm has to decide the ex ante production and price of final good for the coming period while facing stochastic demand (additively stochastic demand function is used). The model is only concerned with the ex ante decisions. Given the initial stock, the consumption of raw material during the present period and the required minimum stock, the ex ante production decision uniquely determines the beginning-of-production-period raw material stock, and therefore also the demand for sawlogs.

Other production factors are ignored, so that the only production costs are the costs of raw material and the carrying costs of raw material stocks. The production function is directly proportional. The firms multiperiod planning problem is collapsed into a one period problem by using an approximation. This approximation gives the effect of end-of-production-period raw material stock or shortage on all expected future profits. It is assumed that in case of shortage raw material can also be acquired during the production period but it is more costly than the stock acquired beforehand (delivery delays, premium for uncertainty etc.). Because the sawlog market is competitive, stumpage prices are not affected by the raw material demand of the representative firm.

In the sawnwood markets, the Hicksian fixed price assumption is used. The firm makes no decisions concerning the price ex ante but decides how much it is prepared to sell at the going price. The firm is a price taker (or it "decides not to change the prices until its future forecasts and underlying long run cost considerations change" (Atkinson, 1981 p. 314)). In either case the firm commits itself to both production (certain amount of raw material is acquired) and price before observing the stochastic component of demand.

The implicit stock adjustment equation is derived by solving the expected profit maximization problem of the firm. This stock adjustment equation is converted into a demand equation by using the stock identity. The model shows that uncertainty about the future and the storability of the raw material are the reasons for the raw material stocks to vary from the level suggested by the simple accelerator of expected demand. For this reason, the demand for the raw material is price flexible, even in the short run. Low stumpage prices make it worth taking greater risk in carrying excess stocks than high stumpage prices. Furthermore, it is not necessarily profitable for the firm to ex ante attempt to buy enough raw material to be prepared to produce the mean expected demand.

The beginning of the production period stock is, according to the theoretical model, an increasing function of expected final good demand and price and expected stumpage price and the initial stock (because of the adjustment costs) and a decreasing function of stumpage price and the carrying costs of stock. In the demand equation qualitative effects of the variables are the same, except that the initial stock decreases the demand and, in addition, the predetermined consumption of raw material during the present period increases it.

The above results are derived under very restrictive assumptions concerning the functional forms used in the model of representative firm, and are therefore by no means general. In spite of this the model of the representative firm is not very easy to handle. These facts must be considered as a drawback of the approach.

The supply of sawlogs is considered under two different behavioral modes: present value maximizing of sales income and utility maximizing with stock and consumption of goods and services in the utility function (chapter 5). The joint product problems of the sawlogs production are ignored except for the fact that for the utility maximizing forest owner the standing stock as such brings utility.

For the present value maximizer (of stumpage income), the supply of sawlogs is concluded to be an increasing function of present price, time preference and initial stock and decreasing function of expected stumpage price. Stumpage price effects in this model are somewhat special. Present prices affect the supply only relative to future prices. Therefore present and future prices enter the supply equation only relative to each other. An expected price increase decreases the present supply because it means relative decrease in the present stumpage price. The effects of exogenous variables on sawlog supply are caused by their effects on the optimal end of the period standing stock.

When the forest owner is a utility maximizer, with standing stock and consumption of goods and services in the utility function (diminishingly increasing with respect to both arguments), exogenous income also affects the supply. According to the one period utility maximizer's model the sawlog supply is an increasing function of stumpage price and initial stock and decreasing function of model exogenous income. The price effect is not ambiguous because the substitution effect of stumpage price on supply is positive but the income effect negative. However, at least in the short run it is realistic to assume that the substitution effect dominates.

For the utility maximizing forest owner the stumpage price relative to other current prices also matters. Therefore the result is different to the one obtained for the present value maximizer. The intertemporal utility maximizing approach showed that the present supply is a function of the present and future values of all exogenous variables of the model (stumpage prices, exogenous income and time preference of the forest owner) although definit signs to these effects were not obtained.

The present value maximizer's model and one period utility maximizer's model were shown to be special cases of the more general intertemporal utility maximizing problem. The experimental estimations with expectation variables and time preference (the interest rate) did not succeed. For this reason the final estimated supply equation is actually derived from the one period utility maximizer's model.

The estimable supply equation is constructed using the stock adjustment model introduced by Houthakker and Taylor (1970).

This specification has the advantage that the stock on which the supply depends does not have to be explicitly included in the estimated equation. The variant of the model employed results in an estimable supply equation with first differences of exogenous variables, and the lagged endogenous variable as explanatory variables.

In chapter 6, the raw material stock adjustment equation for the sawmill industry is initially estimated, after presenting the data. All variables of the stock adjustment equation obtain statistically significant coefficients, although only at 20 per cent risk level in case of stumpage price and expected sawnwood demand. The short run elasticity of the stocks with respect to stumpage price is -0.2 and 0.5 with respect to expected sawnwood price. The adjustment of the stocks is not very rapid, as indicated by the value 0.27 of the adjustment parameter. Accordingly only 27 percentage of the "desired" change of the stock is completed during the period. Slow adjustment is considered plausible in the present case, although it contradicts many earlier empirical results.

After the stock adjustment equation, the simultaneous sawlog market model is estimated using two stage and three stage least squares estimation techniques. The user cost of capital (combined carrying cost of stock and static stumpage price expectations) in the demand equation did not obtain a statistically significant coefficient and was left out from the final model. Otherwise the statistical performance of the demand equation is good, however, the supply equation does not behave very well. The supply equation is autocorrelated and only the coefficient of the first difference of the stumpage price is statistically significant.

The elasticity of sawlog demand with respect to stumpage price is -0.9, and 1.3 with respect to the expected export price. The sawlog demand elasticities with respect to stumpage price and sawnwood price reported by Korpinen (1981) are -0.8 and 0.9 respectively.

The price elasticity of sawlog supply with respect to stumpage price obtained in the present study is 3.1. When the period of agreements for recommended stumpage prices for the whole country is excluded the elasticity of supply with respect to the stumpage price decreases to 2.5. Also, when the model was estimated using annual data (by felling seasons) the elasticity of supply with respect to the stumpage price decreased to 1.8.

The results support the one obtained by Korpinen concerning elastic sawlog supply in the short run. However, the present study indicates even higher elasticity of supply with respect to stumpage price than 1.6 as obtained by Korpinen using nominal prices and commercial fellings. However, especially the results concerning the short run elasticity of supply must be considered tentative. This is specially the case, because the attempts to include price expectations into the roundwood supply equation indicate that the "long run" elasticity of supply may be considerably lower than the short run elasticity (cf. Korpinen 1981; Tervo, 1981 p. 113). When real prices are used the "long run" elasticity may even turn negative (cf. Tervo, 1981 p. 110, 112 and 115; Kuuluvainen, 1982 p. 26), although the result in studies concerned lacks sound theoretical basis.

To test the performance of the present model the commercial fellings with one period lead are also used as the explained variable (semiannual data). One period lead is considered to approximately fit the lag between these two time series. The results support the hypothesis that these two quantity series may lead to different results. All price elasticities of the model decrease in absolute value when commercial fellings is used as the explained variable. The most prominent change is in the stumpage price elasticity of supply, which decreases to 1.7. Somewhat surprising is the increase of the adjusted coefficient of determination of the supply equation in two stage least squares estimation and also the increase of the t-values in the supply equation when commercial fellings are used. The adjusted coefficient of determination in the demand equation decreases. This may be explained by the fact that the demand equation is constructed for ex ante decisions (purchases of sawlogs), whereas commercial fellings are clearly on ex post variable.

In Sweden, Brännlund et al. (1983) report the stumpage price elasticity of sawlog demand to be -0.99 and the elasticity of supply 0.61 (also they use commercial fellings as the explained variable). They consider simultaneously both pulpwood and sawlog supply so that the empirical treatment is more rigorous than that of the present study. The elasticity of sawlog supply with respect to pulpwood price was found to be -0.68. They conclude that it is very difficult to increase sawlog supply by price stimuli if business cycles in the two industries "run in phase". (Brännlund et al., 1983 p. 5). Because the present study concerns only the sawlog market and no semiannual stumpage prices of pulpwood are available, it cannot be said whether a similar situation exist in Finland.

The coefficient of exogenous income (other than stumpage income) obtained negative but statistically nonsignificant parameter estimate in the supply equation. When the period of recommended price agreements is omitted the parameter estimate becomes positive. When commercial fellings is used as the explained variable, the parameter estimate of the exogenous income variable is statistically "almost" significant. Also the absolute value of the elasticity estimate increases.

Disregarding the period from 1970 to 1972, the stock adjustment, demand and supply equations predict the turning points of stock and sawlog sales time series fairly well. The model is also able to predict the development of sales at the end of the 1970's and in the beginning of the 1980's. However, the predicted demand is higher than quantities actually traded whereas the predicted supply is somewhat lower.

In particular the fairly good behaviour of the supply equation is somewhat surprising, because sawlog sales during this time where higher than ever before in Finland. At the same time, real stumpage prices were decreasing or increased only slightly and their absolute level was about the same as at the beginning of the 1970's. Acceptable behaviour of the supply equation is mainly due to the autoregressive nature of the formulation. In reality however, the phenomena is probably explained by larger than optimal standing stock due to a low demand after the mid-1970's and by decreasing price expectations.

Similarly, the overestimated supply during the boom of the mid-1970's is probably due to the fact that the model cannot take into consideration the increasing price expectations of that time. This draws attention to a significant drawback of the present study. The expectations in the demand equation are handled in a very degenerated manner assuming static expectations and are not explicitly considered at all in the estimated supply equation.

Auto- and partial autocorrelation functions and the estimated sawlog stumpage price equations indicate flexible stumpage price adjustment when the semiannual observation period is used. Therefore, the asset motive in the short term stock management decisions, in case of forest owners, may be important feature of the sawlog market in the 1960's and in the 1970's. This further emphasizes the importance of price expectations and supports the implicit assumption of price flexibility made in previous studies concerning the sawlog trade. Lack of observations prevents the conclusions of the effects of the recommended stumpage price agreements, which obviously tend to slow down the speed of adjustment of stumpage prices.

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Appendix 1.

INTERTEMPORAL UTILITY MAXIMIZING PROBLEM OF THE REPRESENTATIVE FOREST OWNER:

By substituting the budget identity (5.16a) and standing stock identity (5.16b) into the intertemporal utility function (5.15)the problem of the representative forest owner can be written (personal communication with Seppo Honkapohja)

(A1.1) $$\text{Max } U = \sum_{t=1}^{T} (1+i)^{1-t} u(s_t, m_t + q_t(s_{t-1} + gs_{t-1} - s_t)).$$

The equilibrium condition is exactly the same as in (5.19) except that, for simplicity, the growth function g is now replaced by a positive constant. This does not affect the qualitative results. The equilibrium condition is

(A1.2) $$u_1^t - u_2^t q_t + (1+i)^{-1} u_2^{t+1} q_{t+1}(1+g) = 0.$$

Totally differentiating with respect to all variables yields the second order differential of U as follows (personal communication with Seppo Honkapohja),

(A1.3)
$$\begin{aligned}
d^2U = & \left[u_{11}^t - 2u_{12}^t q_t - u_{22}^t q_t^2 + (1+i)^{-1} u_{22} q_{t+1}^2 (1+g)^2 \right] ds_t \\
& + \left[u_{12}^t q_t (1+g) - q_t^2 u_{22}^t (1+g) \right] ds_{t-1} \\
& + \left[(1+i)^{-1} u_{21}^{t+1} q_{t+1} (1+g) - (1+i)^{-1} u_{22}^{t+1} q_{t+1}^2 (1+g) \right] ds_{t+1} \\
& + \left[u_{12}^t (s_{t-1} + gs_{t-1} - s_t) - u_2^t - q_t u_{22}^t (s_{t-1} + gs_{t-1} - s_t) \right] dq_t \\
& + \left[(1+i)^{-1} u_2^{t+1} (1+g) + (1+i)^{-1} u_{22}^{t+1} (s_t + gs_t - s_{t+1}) q_{t+1} (1+g) \right] dq_{t+1} \\
& + \left[u_{12}^t - q_t u_{22}^t \right] dm_t + \left[(1+i)^{-1} u_{22}^{t+1} q_{t+1} (1+g) \right] dm_{t+1} \\
& + \left[u_2^{t+1} q_{t+1} (1+g) (-(1+i)^{-2}) \right] di.
\end{aligned}$$

To demonstrate the solution to this problem, the most simple case of two periods is considered. The forest owner revises the plan at the beginning of each period and considers only two periods at the time. Even so the terminal stock of the second period imputes utility to the owner and therefore the stock will not be depleted during the second period.

Rearranging the second order condition so that exogenous variables enter to the left hand side, and exogenous to the right hand side the following system of two equations and two unknowns (ds_1 and ds_2) is obtained

$$\text{(A1.4)} \quad \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} ds_1 \\ ds_2 \end{bmatrix} = b_{11} ds_0 + \begin{bmatrix} c_{11} & c_{12} \\ 0 & c_{22} \end{bmatrix} \begin{bmatrix} dm_1 \\ dm_2 \end{bmatrix}$$

$$+ \begin{bmatrix} d_{11} & d_{12} \\ 0 & d_{22} \end{bmatrix} \begin{bmatrix} dq_1 \\ dq_2 \end{bmatrix} + e_{11} di.$$

The values of the coefficient matrices of ds_i, ds_0, dm_i, dq_i and di (where subscript i=1,2) are obtained from the second order condition (A1.3) and are given below. To make a difference between the derivatives of the utility function with respect to the values of exogenous variables of the two periods circled superscripts $\textcircled{0}$=t-1, $\textcircled{1}$=t and $\textcircled{2}$=t+1 are used. For variables circled subscripts are used for the same purpose.

$$a_{11} = u^{\textcircled{1}}_{11} - 2u^{\textcircled{1}}_{12} + u^{\textcircled{1}}_{22} q_1^2 + (1+i)^{-1} u^{\textcircled{2}}_{22} q^2_{\textcircled{1}} (1+g)^2 < 0,$$

$$a_{12} = (1+i)^{-1} q_{\textcircled{2}} (i+g) (u^{\textcircled{2}}_{21} - u^{\textcircled{2}}_{22} q_{\textcircled{2}}) > 0,$$

$$a_{21} = (i+g) q_{\textcircled{1}} (u^{\textcircled{1}}_{12} - q_1 u^{\textcircled{1}}_{22}) > 0,$$

$$a_{22} = u^{\textcircled{2}}_{11} - 2u^{\textcircled{2}}_{12} q_{\textcircled{2}} + u^{\textcircled{2}}_{22} q^2_{\textcircled{2}} + (1+i)^{-1} u^{\textcircled{2}}_{22} q_{\textcircled{2}} (1+g)^2 < 0,$$

$$b_{11} = - \left[(1+g)\, q_{\textcircled{1}} (u_{12}^{\textcircled{1}} - q_1 u_{22}^{\textcircled{2}})\right] < 0,$$

$$c_{11} = - \left[u_{12}^{\textcircled{1}} - q_{\textcircled{1}} u_{22}^{\textcircled{1}}\right] < 0,$$

$$c_{12} = - \left[(1+i)^{-1} (i+g)\, u_{22}^{\textcircled{2}} q_{\textcircled{2}}\right] > 0,$$

$$c_{22} = - \left[u_{12}^{\textcircled{2}} - q_{\textcircled{2}} u_{22}^{\textcircled{2}}\right] < 0,$$

$$d_{11} = - \left[u_{12}^{\textcircled{1}} x_{\textcircled{1}} - u_{2}^{\textcircled{1}} - q_{\textcircled{1}} u_{22}^{\textcircled{1}} x_{\textcircled{1}}\right] > 0,$$

where $x_1 = s_0 + gs_0 - s_1$,

$$d_{12} = - \left[(1+i)^{-1} (1+g)\, (u_{2}^{\textcircled{2}} + u_{22}^{\textcircled{2}} q_{\textcircled{2}} x_{\textcircled{2}})\right] < 0,$$

where $x_2 = s_1 + gs_1 - s_2$,

$$d_{22} = - \left[u_{12}^{\textcircled{2}} x_{\textcircled{2}} - u_{2}^{\textcircled{2}} - q_{\textcircled{2}} u_{22}^{\textcircled{2}} x_{\textcircled{2}}\right] > 0 ,$$

where $x_2 = s_1 + gs_1 - s_2$,

$$e_{11} = \left[u_{2}^{\textcircled{2}} q_{\textcircled{2}} (1+g)\, (1+i)^{-2}\right] > 0 .$$

The effects of the changes in exogenous variables on the optimal end of periods stocks of periods one and two can be solved using Cramer's rule (see Kuska, 1973 for the Cramer's rule for solving linear equations and for the first and second order conditions in classical unconstraint and constraint optimization). The second order condition for maximum requires that a_{11} is negative and A, the determinant of the coefficient matrix on the left hand side, is positive (Kuska, 1973 p. 77). Using this, and the signs of the elements of the coefficient matrices, which are obtained from the assumptions made about the form of the utility function (p. 53), the comparative statics of the model, the changes of the optimal stock level with respect to changes in exogenous variables are as follows

(A1.5a) $$\frac{ds_1}{ds_0} = \frac{b_{11}a_{22}}{A_2} > 0, \quad \frac{ds_2}{ds_0} = \frac{-b_{11}a_{21}}{A_2} > 0,$$

(A1.5b) $$\frac{ds_1}{dm_1} = \frac{c_{11}a_{22}}{A_2} > 0, \quad \frac{ds_2}{dm_1} = \frac{-c_{11}a_{21}}{A_2} > 0,$$

(A1.5c) $$\frac{ds_1}{dm_2} = \frac{c_{12}a_{22} - c_{22}a_{12}}{A_2} \gtrless 0, \quad \frac{ds_2}{dm_2} = \frac{a_{11}c_{22} - a_{21}c_{12}}{A_2} \gtrless 0,$$

(A1.5d) $$\frac{ds_1}{dq_1} = \frac{d_{11}a_{22}}{A_2} < 0, \quad \frac{ds_2}{dq_1} = \frac{-d_{11}a_{21}}{A_2} < 0,$$

(A1.5e) $$\frac{ds_1}{dq_2} = \frac{d_{12}a_{22} - d_{22}a_{12}}{A_2} \gtrless 0, \quad \frac{ds_2}{dq_2} = \frac{a_{11}d_{22} - a_{21}d_{12}}{A_2} \gtrless 0,$$

(A1.5f) $$\frac{ds_1}{di} = \frac{e_{11}a_{22}}{A_2} < 0, \quad \frac{ds_2}{di} = \frac{-e_{11}a_{21}}{A_2} < 0.$$

In order to convert these effects of exogenous variables on optimal end of period stock to effects on (sawlog) supply, the identity giving the evolution of standing stock as a function of growth and fellings (=supply) can be used. The value of the end of period one stock is

$$(A1.6)\ s_1 = s_0 + gs_0 - x_1,$$

which can be solved for fellings (x_1)

$$(A1.7)\ x_1 = s_0 + gs_0 - s_1.$$

The second period fellings can be similarly written as

$$(A1.8)\ x_2 = s_1 + gs_1 - s_2.$$

From (A1.7) it can be seen that the change in optimal end-of-period stock level changes first period optimal supply to opposite direction by the same amount that is

$$\frac{dx_1}{ds_1} = -1.$$

Solving the first period fellings as a function of initial stock, growth and second period fellings and end of second period optimal stock gives

$$(A1.9)\ x_1 = \frac{1}{1+g}(s_0(1+2g+g^2)-x_2-s_2).$$

This shows that the change in the end of second period optimal stock, caused by the change in exogenous variables of the model, also effects the present period fellings, as before, to the opposite direction. Because of growth of the stand, the effect is, however, less than the effect of the end-of-first-period optimal stock, that is

$$\frac{dx_1}{ds_2} = - \frac{1}{1+g},$$

so that the effect of growth has been taken into account.

Considering all possibilities of this simple two period discrete time model already gets rather complicated. Comparative statics results in (A1.5) also show that only the effects of present period changes in the exogenous variables have unambiguous effects on the optimal stock level.

Detailed discussion of the results of this model is out of the scope of the present study, and possible reformulation of the forest owner's maximizing problem is left for further work. For this reason, only the first period supply of sawlogs resulting from this model is presented.

Using the fact that $dx_1/ds_1 = -1$, it is seen that an increase in present period stumpage price, in the forest owner's time preference or in initial stock all increase the first period supply (A1.5a, A1.5d A1.5f). An increase in the present period exogenous income decreases it (A1.5b).

The partial derivate of the end-of-first-period-stock with respect to initial stock is, however, somewhat special. Let us assume that the forest owner obtains from some source larger initial stock. From the stock identity it is seen that it is now possible for him to sell more timber and still attain the same utility level from the end-of-period-standing stock, as before. Stumpage income brings utility through consumption of goods and services and this utility was assumed to be non decreasing with respect to consumption of goods and services. The total utility is therefore increased by selling more.

In an intertemporal steady state solution, only the initial stock is exogenous. When the plan is also formulated at the beginning of each period, each period initial stock is exogenous, and implicitly imperfect information and adjustment costs are assumed.

The comparative static results of this two period model give the following implicit sawlog supply function

(A1.10) $$x^s = x^s(\underset{+}{q_t}, \underset{-}{m_t}, \underset{+}{i}, \underset{+}{s_{t-1}};\ \underset{+/-}{q_{t+1}}, \underset{+/-}{m_{t+1}}),$$

where time preference is a constant parameter. The second period values of exogenous variables, which in empirical analysis would be expectation variables, do not get definite signs.

The complete intertemporal steady state solution of the model does not give signs to any of the effects of the exogenous variables. This complete solution would require a four period model (personal communication with Seppo Honkapohja). For example, the effects of changes in exogenous income on optimal end-of-periods-stocks would be, analogously with the two period case, possible to compute from the following system of four unknowns and four equations ($ds_0=dq_t=di=0$)

$$\text{(A1.11)} \quad \begin{bmatrix} a_{11} & a_{12} & 0 & 0 \\ a_{21} & a_{22} & a_{23} & 0 \\ 0 & a_{22} & a_{33} & a_{34} \\ 0 & 0 & a_{43} & a_{44} \end{bmatrix} \begin{bmatrix} ds_1 \\ ds_2 \\ ds_3 \\ ds_4 \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} & 0 & 0 \\ 0 & c_{22} & c_{23} & 0 \\ 0 & 0 & c_{33} & c_{34} \\ 0 & 0 & 0 & c_{44} \end{bmatrix} \begin{bmatrix} dm_1 \\ dm_2 \\ dm_3 \\ dm_4 \end{bmatrix}$$

$$\qquad\qquad A \qquad\qquad\qquad ds \qquad\qquad\qquad C \qquad\qquad\qquad dm$$

The elements of the coefficient matrices are again obtained from the second order condition (A1.3), but because the results remain ambiguous it is in order only to observe the sign pattern of the coefficient matrices which cause the ambiguity. The result is evident by observing the sign pattern of the A and C matrices of the four period model. All coefficient matrices of the differentials of the exogenous variables have the same sign pattern as those in (A1.4) (the coefficient matricies of ds_0 and di have zeros everywhere, except on the main diagonal). The elements of A and C matrices have the following signs

$$A: \begin{matrix} - & + & 0 & 0 \\ + & - & + & 0 \\ 0 & + & - & + \\ 0 & 0 & + & - \end{matrix} \qquad\qquad C: \begin{matrix} - & + & 0 & 0 \\ 0 & - & + & 0 \\ 0 & 0 & - & + \\ 0 & 0 & 0 & - \end{matrix}$$

Cramer's rule is used in the same manner as above in the two period case. The fourth determinant of the A matrix has to be positive for the second order condition for maximum to hold (Kuska, 1973 p. 77). Therefore the denominator always has a definite sign. The signs of the numerators (the determinants of the A matrix after substitution of relevant columns of the coefficients matrices of exogenous variables) remain ambiguous. The ambiguity of the results seems to be independent of the form of the utility function as long as the assumptions of positive first and negative second and nonnegative cross derivatives are not abandoned. One reason for the ambiguity is the dynamic standing stock constraint, which binds the successive periods together. It might be possible to obtain more definitite results if, for example, the life cycle of the owner could be more realistically modelled. This would require the possibility of savings and also possibility of substitution of consumption between the periods. Evidently a problem in this case could be best solved by using continuous time techniques. Introducing these features into the above two period model might already bring more information about the phenomenon. This is left for further work.

Appendix 2.

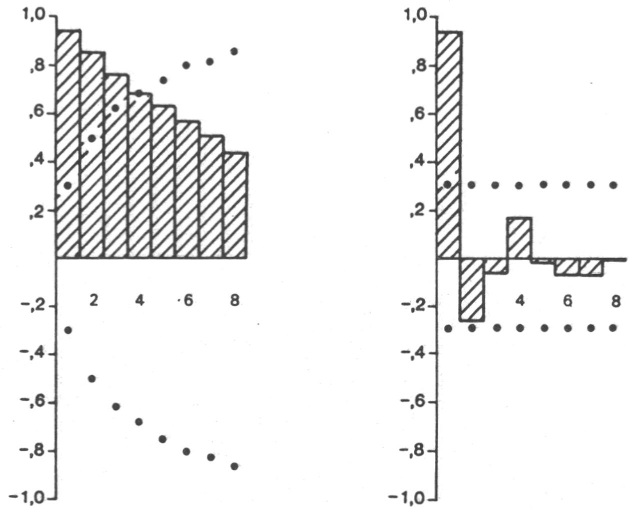

Figure A1. Autocorrelation (a) and partial autocorrelation (b) functions of the nominal export unit value of sawnwood, semiannual observations 1960/1-1981/1.

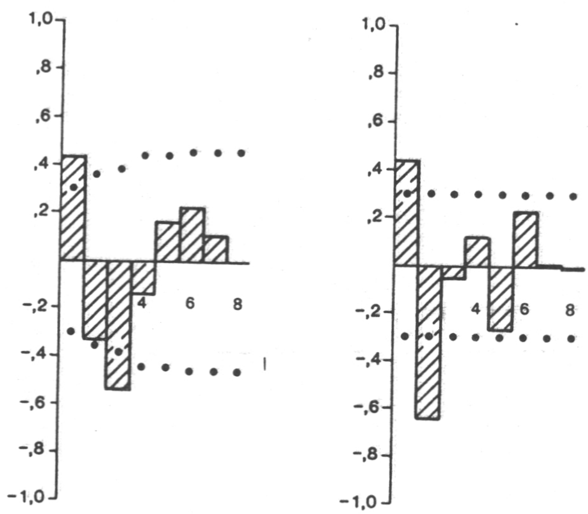

Figure A2. Autocorrelation (a) and partial autocorrelation (b) functions of the first differences of the nominal export unit value of sawnwood, semiannual observations 1960/1-1981/1.

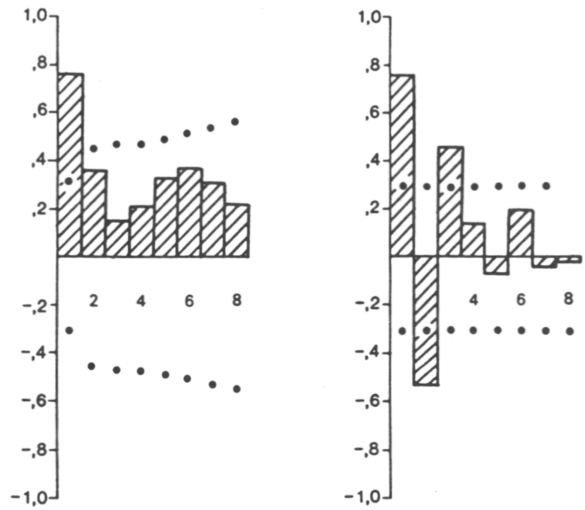

Figure A3. Autocorrelation (a) and partial autocorrelation (b) functions of the real export unit value of sawnwood, semiannual observations 1960/1-1981/1.

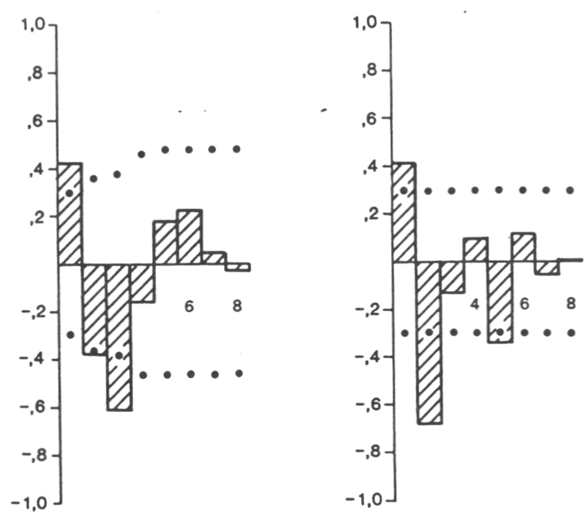

Figure A4. Autocorrelation (a) and partial autocorrelation (b) functions of the first differences of the real export unit value of sawnwood, semiannual observations 1960/1-1981/1.

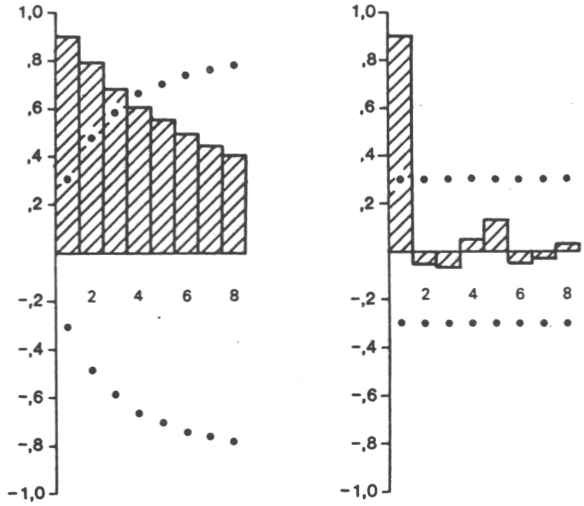

Figure A5. Autocorrelation (a) and partial autocorrelation (b) functions of the nominal stumpage prices of sawlogs, semiannual observations 1960/1-1981/1.

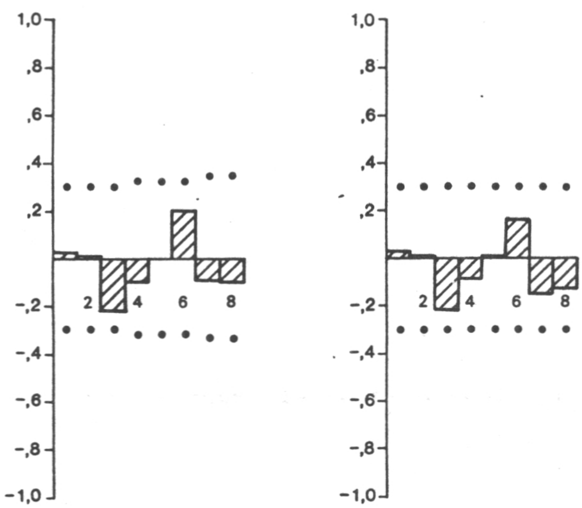

Figure A6. Autocorrelation (a) and partial autocorrelation (b) functions of the first differences of the nominal stumpage prices of sawlogs, semiannual observations 1960/1-1981/1.

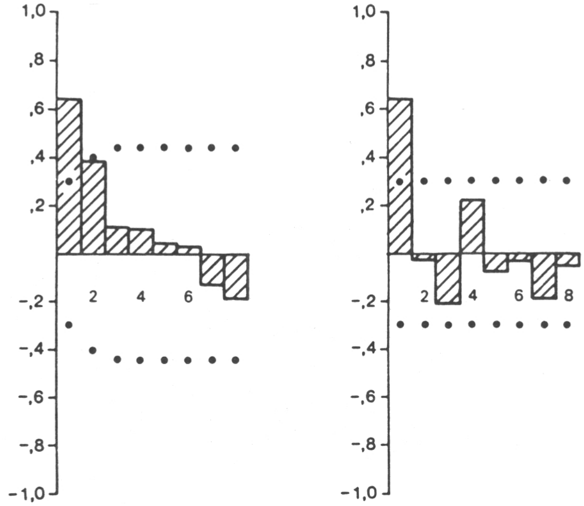

Figure A7. Autocorrelation (a) and partial autocorrelation (b) functions of the real stumpage prices of sawlogs, semiannual observations 1960/1-1981/1.

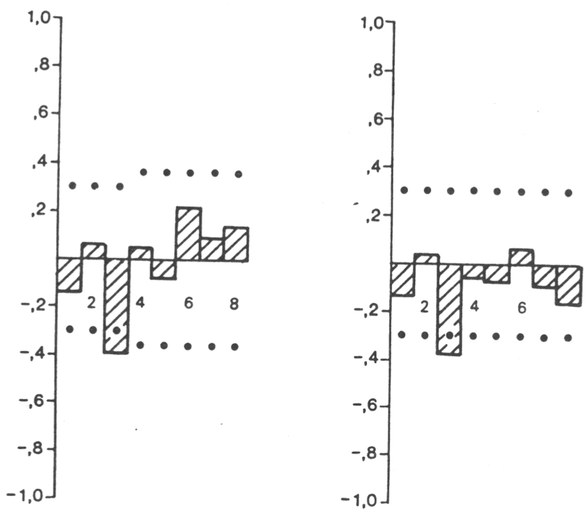

Figure A8. Autocorrelation (a) and partial autocorrelation (b) function of the first differences of the real stumpage prices of sawlogs, semiannual observations 1960/1-1981/1.

Appendix 3.

SAMPLING: Semiannual sawlog stumpage prices and the purchases from private nonindustrial forest.

The official statistics of Finland only report semiannual observations of commercial fellings (since 1960) but give no figures of purchases of roundwood from private nonindustrial forests. Stumpage prices were reported annually until 1978, since then semiannual observations are available. As indicated by figure A9, the difference between commercial fellings and purchases of timber is considerable even in the yearly data. The commercial fellings therefore do not necessarily reflect the supply-demand situation in the roundwood markets

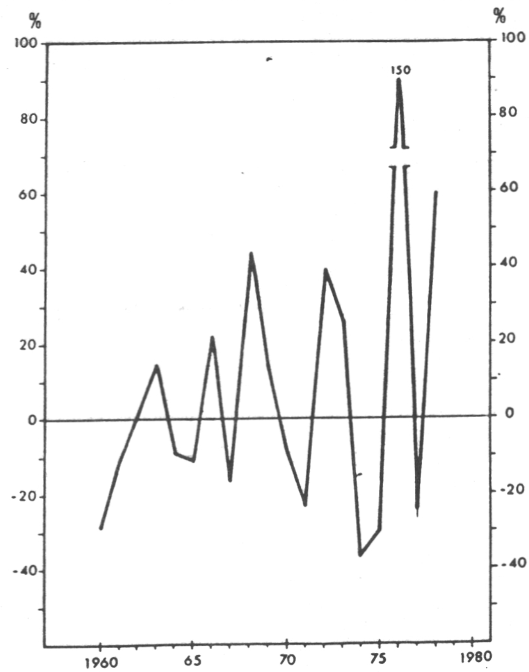

Figure A9. Differences of yearly percentage changes of sawlog purchases from private nonindustrial forests and commercial fellings, 1960 - 1978.

For the present study, sawlog stumpage prices and sawlog purchases from private nonindustrial forests were collected during the period 1960-1981. Until the first half of 1980, the semiannual basic data of the forest taxation was used. This data was collected by the Mathematics Department of the Finnish Forest Research Institute). From 1980/2 onwards, observations have been taken from the archives of the Central Association of the Finnish Forest Industries.

The forest taxation data contains observations of average prices and quantities purchased semiannually from 464 Finnish communes. To avoid excessive computions a sample of

100 communes was taken with the help of Mathematics Department. Sampling with proportional probabilities was used. The probability of the commune to enter the sample was proportional to the amount of commercial fellings during the base year. 1973 was selected as the base year because it was the boom year and therefore probably gives a better picture of the cutting possibilities of the commune than a depression or 'average' year.

The quantity and price estimates ($\hat{Y}$ and $\hat{H}$ respectively) were calculated as follows

$$\hat{Y} = \frac{1}{n} \cdot \bar{X}\Sigma \frac{Y_{ij}}{x_i}, \quad \hat{H} = \frac{(y_{ij}h_{ij})/x_i}{y_i/x_i},$$

where n - number of observations

X - $\sum_{i=1}^{2} x_i$, the total purchases of sawlogs during the base year, 1973

y_{ij} - the quantity purchased in the sampling unit (commune) i during the semi-year (i=1,...100; j=1,2)

x_i - the quantity purchased during the base year in commune i

$\hat{Y}$, $\hat{H}$ - quantity and price estimates for the whole country.

The variances for quantity and price are obtained from

$$\sigma_{\hat{Y}}^2 = \left(\frac{1}{n} - \frac{1}{N}\right)\frac{1}{n-1}\bar{X}^2\left[\sum_{i=1}^{n}\left(\frac{y_{ij}}{X_i}\right)^2 - \frac{1}{n}\left(\sum_{i=1}^{n}\frac{y_{ij}}{X_i}\right)^2\right] \text{ and}$$

$$\sigma_{\hat{H}}^2 = \frac{N-n}{N}\,\frac{n}{n-1}\,\frac{1}{\left(\Sigma\frac{y_{ij}}{X_i}\right)} B, \quad \text{where}$$

$$B = \sum_{i=1}^{n}\left(\frac{y_{ij}h_{ij}}{X_i}\right)^2 + C^2\sum_{i=1}^{n}\left(\frac{y_{ij}}{X_i}\right)^2 - 2C\sum_{i=1}^{n}\left(\frac{y_{ij}h_{ij}}{X_i}\cdot\frac{y_{ij}}{X_i}\right),$$

$$C = \frac{\sum_{i=1}^{n} (y_{ij} h_{ij})/x_i}{\sum_{i=1}^{n} \frac{y_{ij}}{xi}} .$$

The table below reports error percentages P_{ji} (i=1,2 and $j=\hat{Y},\hat{H}$)) with different sample sizes. P_{ji}:s are approximated from the 95 % confidence intervals in the following way: Denote $\hat{Y} \pm 2 * \sigma_{\hat{Y}i}$ by $\hat{Y} \pm P_{\hat{Y}i} * \hat{Y}$ so that $P_{\hat{Y}i} = (2\sigma_{\hat{Y}i})/\hat{Y}$, i=1,2 (for the first and second half of the year). When computing error percentages, $\hat{Y}$ and $\sigma_{\hat{Y}i}$ ($\hat{H}$ and $\sigma_{\hat{H}i}$) were calculated using the material of the base year (the total purchases in all communes).

Table A1. Error percentages (P_{ji}) with different sample sizes.

n	Quantity		Price	
	spring	autumn	spring	autumn
	$P_{\hat{Y}1}$	$P_{\hat{Y}2}$	$P_{\hat{H}1}$	$P_{\hat{H}2}$
400	3.3	3.7	0.6	1.3
350	4.7	5.2	0.9	1.9
300	6.1	6.8	1.2	2.5
200	9.4	10.5	1.8	3.8
100	15.6	17.5	3.0	6.4
50	23.6	26.3	4.6	9.6
25	34.3	38.3	6.6	14.0
20	38.6	43.1	7.5	15.8

The error percentage is larger in the quantity estimates. However, the sample size of 100 was considered to give satisfactory results, because beyond this the improvement in accuracy was only possible with considerably larger sample sizes. In figure (A10) the stumpage prices obtained from the sample are compared to those calculated from the total data of the yearly prices (Official statistics of Finland XVII A:13).

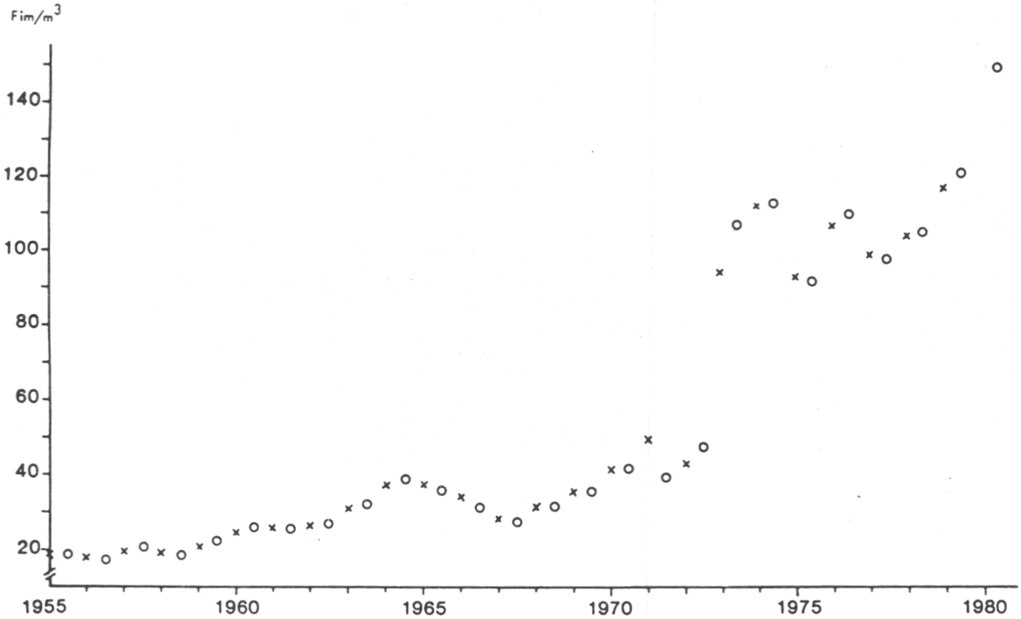

Figure A10. Sawlog prices from total data (oooo) given by the Official observations Statistics of Finland XVII A:13 (different years) by felling seasons (from to VI month of and the year) and yearly sawlog stumpage prices (xxxx) given by the 100 commune sample use in the present study.

Appendix 4.

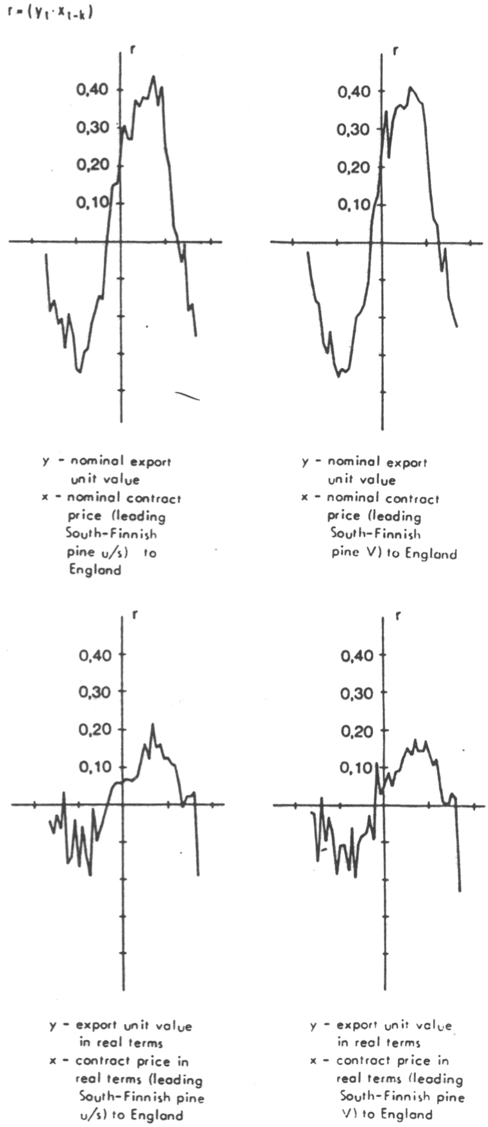

Figure A11. Cross correlation functions of the export unit value of sawnwood and contract prices of two sawnwood grades to England, monthly observations from 1972/1 to 1982/12.

Appendix 5.

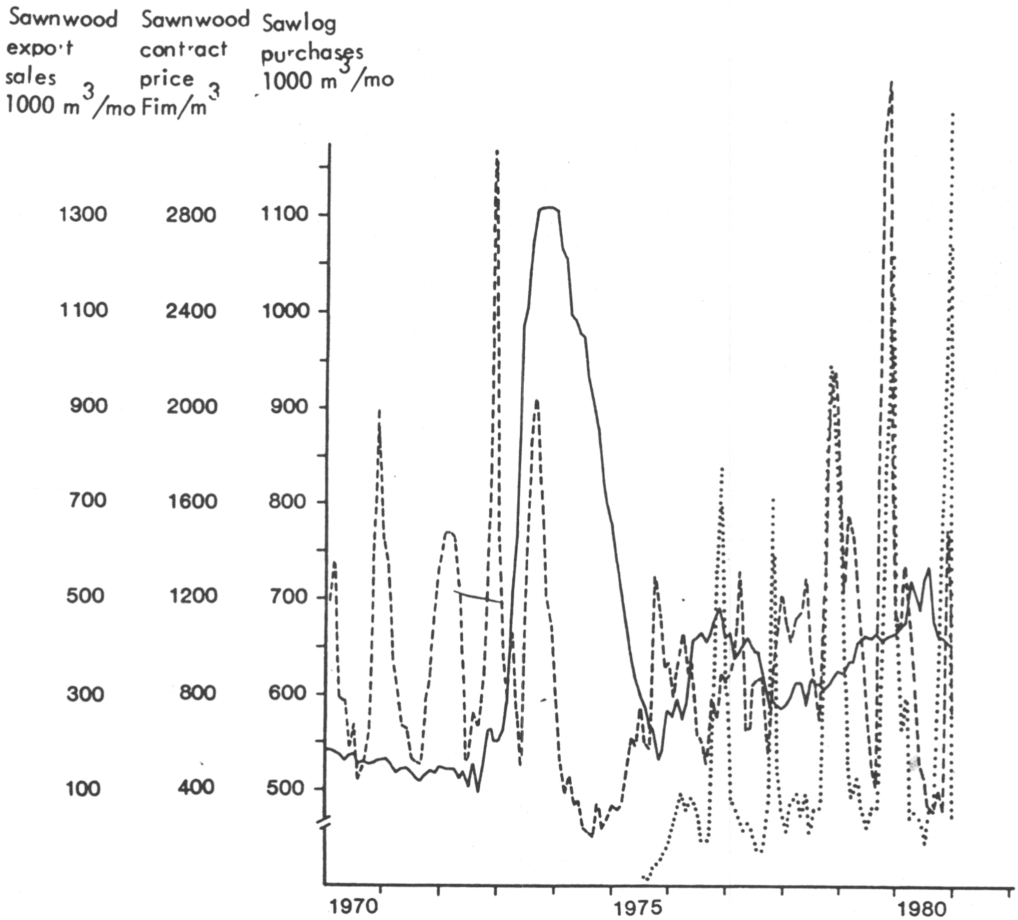

Figure A12. Sawnwood export sales, contract price of sawnwood grade I-IV to England from 1970/1 to 1980/12 and purchases of sawlogs from private non-industrial forests from 1975/8 to 1980/12 (source: the archives of the Central Association of the Finnish Forest Industries and of the Finnish Sawmill Owner's Association).

Appendix 6.

Table A2. Two stage and three stage least squares results of the sawlog market model, when the explained variable is commercial fellings with one period lead.

Independent variables	2SLS Demand	2SLS Supply	3SLS Demand	3SLS Supply
C	9033.14	12803.51	8939.00	14067.67
	(3.05)	(5.90)	(3.30)	(6.35)
Q_t	-57.59		-51.34	
	(2.82)		(2.85)	
$P^e_{t,t+1}$	9.97		9.73	
	(3.11)		(3.33)	
$Z^e_{t,t+1}$	0.92		0.91	
	(3.05)		(3.30)	
$K_t+\bar{U}_t$	0.14		0.11	
	(1.18)		(1.02)	
$\hat{Q}_t$		61.36		64.87
		(4.73)		(5.05)
$\hat{M}_t$		-0.22		-0.20
		(2.16)		(1.78)
X_{t-1}		0.16		0.07
		(1.12)		(0.48)
D3	1780.00	6642.07	2199.58	6730.69
	(0.89)	(3.63)	(1.12)	(3.76)
$\bar{R}^2$	0.25	0.52	0.30	0.33
D-W	1.67	1.65	1.64	1.66
h	-	2.74	-	3.12
ρ	0.47	0.47	0.47	0.47

Structural parameters of the supply equation:
(G=0, Γ_0 not determined,) Γ_1=1.74 Γ_2=121.25, Γ_3=-0.37

Elasticities (from 3SLS estimates)

Variable	Demand	Supply
Stumpage price	-0.7	1.7
Export price	0.6	-
Exogenous income	-	-0.9

The estimate of ρ was computed using linear two stage least squares method for supply and demand equations and because the estimates for these two equations did not differ very much (dem. 0.52, supp. 0.45) an average value was used in transforming the data for nonlinear estimation.

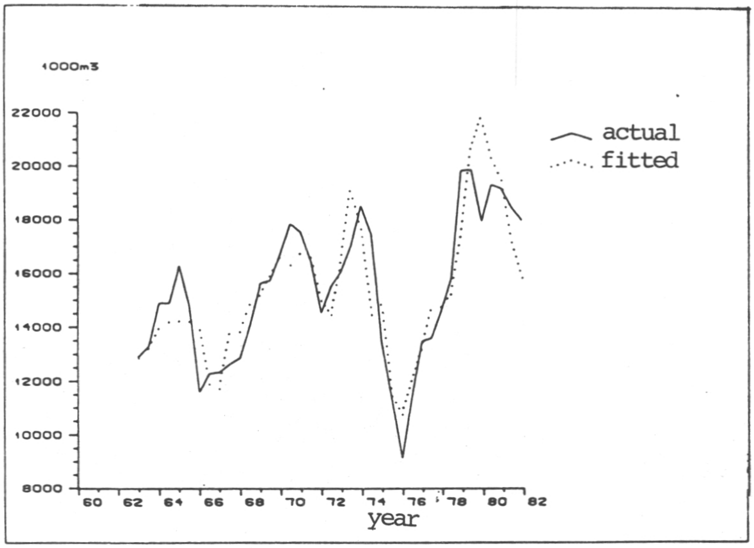

Figure A13. Actual and fitted values of the demand equation with commercial fellings as the explained variable (3SLS).

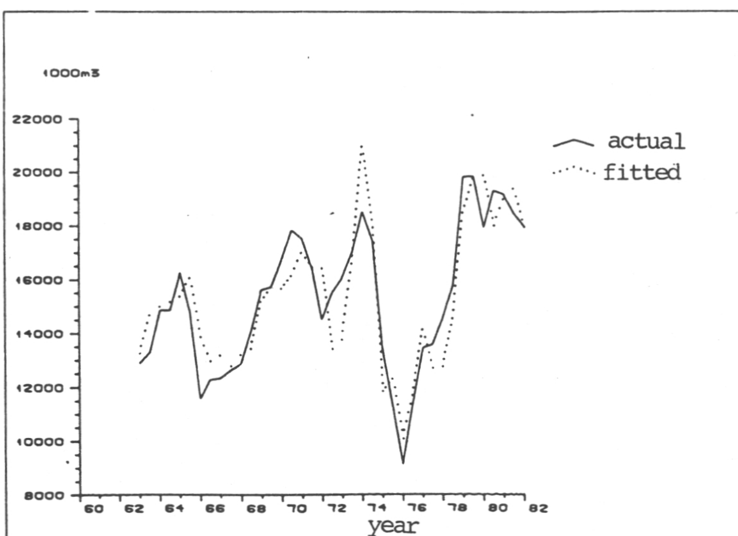

Figure A14. Actual and fitted values of the supply equation with commercial fellings as the explained variable (3SLS estimation results are only plotted because the difference to two stage method is not very big)

Appendix 7.

PLOTS OF ACTUAL AND FITTED VALUES OF ESTIMATED PRICE EQUATIONS (TABLE 2, p. 93)

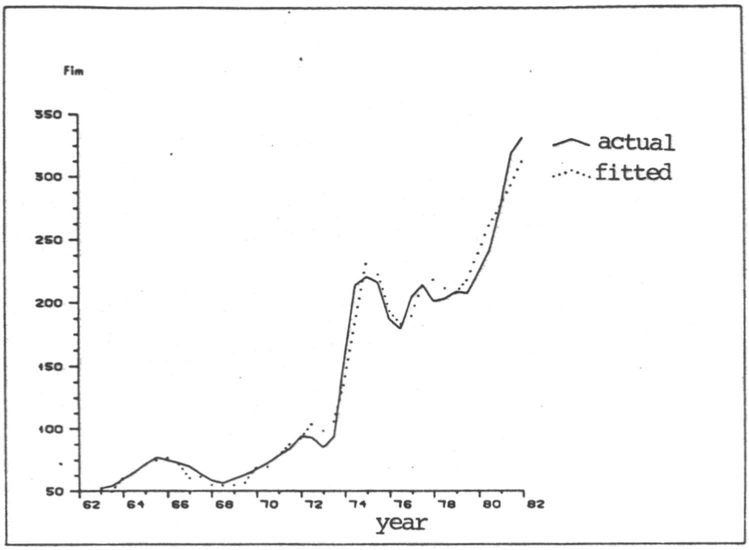

Figure A15. Actual and fitted values of nominal price equation in table 2, column 1, "reduced form", seasonally adjusted observations.

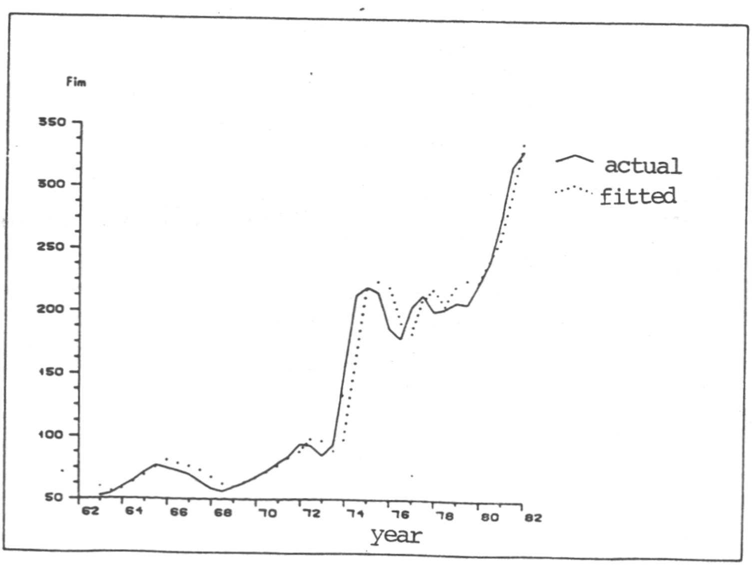

Figure A16. Actual and fitted values of nominal price equation in table 2, column 2, lagged price, seasonally adjusted observations.

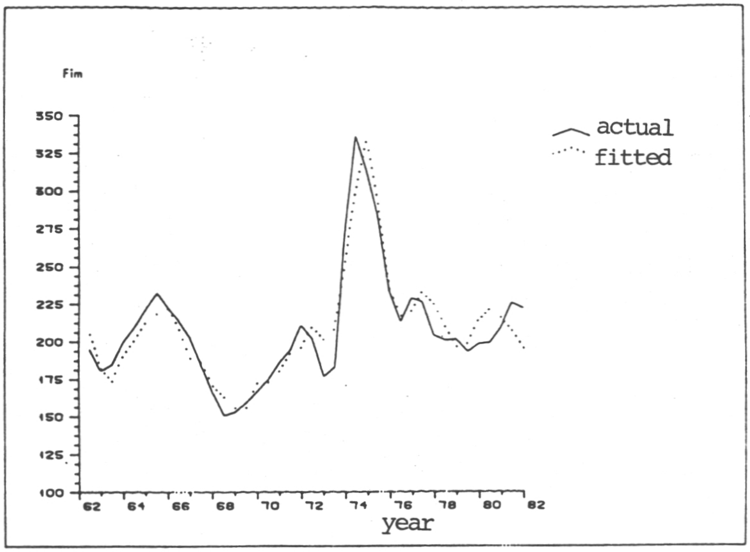

Figure A17. Actual and fitted values of real price equation in table 2, column 3, "reduced form", seasonally adjusted observations.

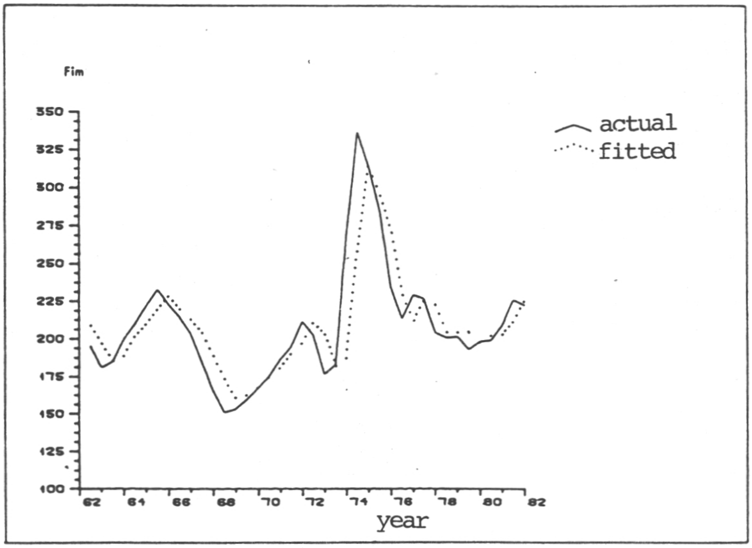

Figure A18. Actual and fitted values of real price equation in table 2, column 4, lagged price, seasonally adjusted observations.

Appendix 8.

Table A3. The estimated reduced form price change equation and quantity equation of sawlog market model (6.12).

Independent variables	Stumpage price Change, ΔQ_t	Sales of sawlogs, X_t
C	-77.47	-3677.80
	(2.86)	(1.66)
$Z^e_{t,t+1}$	0.01	0.65
	(3.60)	(2.82)
$P^e_{t,t+1}$	0.08	10.98
	(3.82)	(6.26)
Q_{t-1}	-0.25	-25.50
	(2.81)	(3.18)
ΔM_t	0.0001	-0.17
	(0.06)	(1.74)
$(K_t+\bar{U}_t)$	0.0009	0.07
	(0.65)	(0.57)
X_{t-1}	-0.02	0.34
	(0.84)	(1.76)
D3	-13.72	3590.32
	(0.98)	(3.13)
R^2	0.64	0.90
$\bar{R}^2$	0.56	0.88
D-W	1.33	1.90

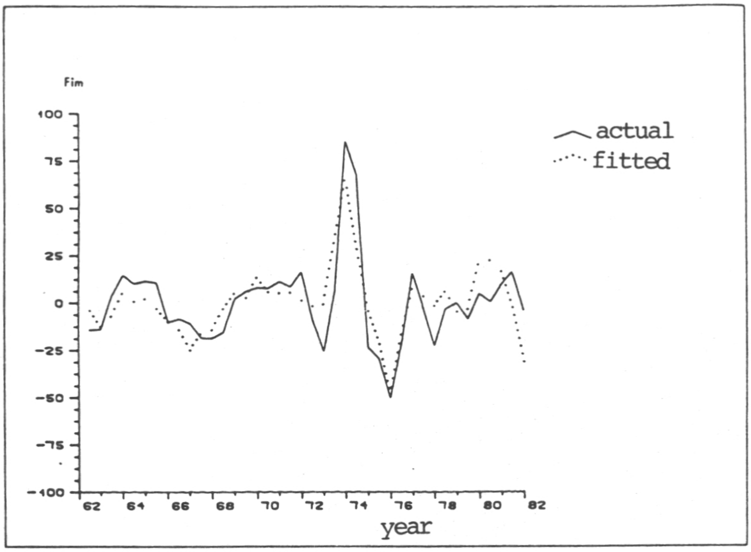

Figure A19. Actual and fitted values of the stumpage price change equation, reduced form, real prices.

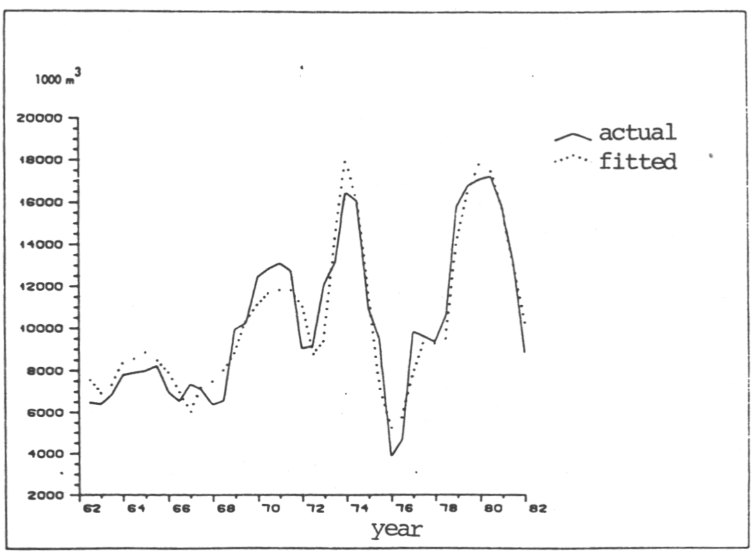

Figure A20. Actual and fitted values of the reduced form sawlog sales equation.

Appendix 9.

Table A4. Three stage least squares results of the sawlog market model using annual data by felling seasons from 1962/63 to 1979/80.

Independent variable	Demand	Supply
C	-10728.02	7514.20
	(3.87)	(4.59)
Q_t	-66.06	
	(2.11)	
$P^e_{t,t+1}$	28.42	
	(4.35)	
$Z^e_{t,t+1}$	1.85	
	(4.92)	
$(K_t+\bar{U}_t)$	0.29	
	(1.85)	
$\hat{Q}_t$		106.81
		(4.47)
$\hat{M}_t$		0.05
		(0.59)
X_{t-1}		0.19
		(1.03)
D3	860.81	5630.96
	(0.51)	(2.61)
$\bar{R}^2$	0.82	0.60
D-W	2.04	2.40

Elasticities:

	Demand	Supply
Stumpage price	-0.67	1.83
Export price	1.31	-
Exogenous income	-	..

The export unit value with one period lead is used as a proxy variable for expected price ($P^e_{t,t+1}$) and the export sales with one period lag as a proxy variable for expected demand ($Z^e_{t,t+1}$).

Appendix 10.

Table A5. Means, standard deviations and minimum and maximum values of the variables used in the estimations.

	MEAN	STD DEV	MINIMUM	MAXIMUM
X(t)	10357.94	3701.84	3848.00	17277.00
X(t-1)	10304.27	3738.90	3848.00	17277.00
MH(t+1)	15253.16	2672.63	9125.51	19885.95
MH(t)	15111.57	2673.18	9125.51	19885.95
Q(t-1)	208.12	38.77	150.47	337.16
ΔQ(t)	0.35	23.39	-50.34	86.03
M(t-1)	35174.86	42130.11	3252.02	161590.89
ΔM(t)	4406.55	5677.31	152.40	20280.92
I(t-1)	14.20	5.07	7.00	24.88
ΔI(t)	0.04	4.06	-9.09	11.21
K(t+1)	18725.53	5620.82	11168.00	30959.00
K(t)	18468.63	5596.49	11168.00	30959.00
Z^e(t,t+1)	4413.30	1275.94	774.00	6834.00
P^e(t,t+1)	961.64	137.17	816.98	1407.48
RQ(t)	13.32	12.00	-29.37	38.83
Q(t)	208.47	38.84	150.47	337.16
(K(t)+U(t))	31594.65	7370.75	22387.84	46240.80

Appendix 11.

Table A6. Correlation matrix of variables used in estimations.

		1	2	3	4	5	6	7	8	9
$X(t)$	1	1.00	0.81	0.87	0.33	-0.16	0.54	0.45	0.48	-0.44
$X(t-1)$	2	0.81	1.00	0.68	0.31	0.16	0.33	0.56	0.64	-0.36
$MH(t+1)$	3	0.87	0.68	1.00	0.36	-0.41	0.55	0.48	0.45	-0.35
$MH(t)$	4	0.33	0.31	0.36	1.00	-0.10	0.22	0.15	0.15	-0.13
$Q(t-1)$	5	-0.16	0.16	-0.41	-0.10	1.00	-0.30	0.16	0.25	0.24
$\Delta Q(t)$	6	0.54	0.33	0.55	0.22	-0.30	1.00	-0.01	0.06	-0.12
$M(t-1)$	7	0.45	0.56	0.48	0.15	0.16	-0.01	1.00	0.95	-0.01
$\Delta M(t)$	8	0.48	0.64	0.45	0.15	0.25	0.06	0.95	1.00	-0.05
$I(t-1)$	9	-0.44	-0.36	-0.35	-0.13	0.24	-0.12	-0.01	-0.05	1.00
$\Delta I(t)$	10	0.09	0.10	0.01	0.00	0.03	0.11	0.01	0.08	-0.40
$K(t+1)$	11	0.80	0.90	0.62	0.25	0.30	0.41	0.63	0.71	-0.27
$K(t)$	12	0.54	0.83	0.36	0.17	0.54	0.12	0.66	0.75	-0.13
$Z^e(t,t+1)$	13	0.71	0.67	0.64	0.28	-0.10	0.57	0.19	0.32	-0.25
$p^e(t,t+1)$	14	0.60	0.44	0.36	0.13	0.19	0.52	0.20	0.25	-0.22
$RQ(t)$	15	-0.63	-0.43	-0.61	-0.20	0.34	-0.89	0.01	-0.06	0.41
$Q(t)$	16	0.16	0.36	-0.08	0.03	0.82	0.30	0.16	0.28	0.17
$(K(t)+U(t))$	17	0.66	0.90	0.52	0.23	0.41	0.20	0.72	0.80	-0.17

		10	11	12	13	14	15	16	17
$X(t)$	1	0.09	0.80	0.54	0.71	0.60	-0.63	0.16	0.66
$X(t-1)$	2	0.10	0.90	0.83	0.67	0.44	-0.43	0.36	0.90
$MH(t+1)$	3	0.01	0.62	0.36	0.64	0.36	-0.61	-0.08	0.52
$MH(t)$	4	0.00	0.25	0.17	0.28	0.13	-0.20	0.03	0.23
$Q(t-1)$	5	0.03	0.30	0.54	-0.10	0.19	0.34	0.82	0.41
$\Delta Q(t)$	6	0.11	0.41	0.12	0.57	0.52	-0.89	0.30	0.20
$M(t-1)$	7	0.01	0.63	0.66	0.19	0.20	0.01	0.16	0.72
$\Delta M(t)$	8	0.08	0.71	0.75	0.32	0.25	-0.06	0.28	0.80
$I(t-1)$	9	-0.40	-0.27	-0.13	-0.25	-0.22	0.41	0.17	-0.17
$\Delta I(t)$	10	1.00	0.18	0.12	-0.03	0.14	0.05	0.09	0.11
$K(t+1)$	11	0.18	1.00	0.90	0.53	0.65	-0.44	0.55	0.93
$K(t)$	12	0.12	0.90	1.00	0.36	0.45	-0.15	0.61	0.98
$Z^e(t,t+1)$	13	-0.03	0.53	0.36	1.00	0.26	-0.63	0.25	0.50
$p^e(t,t+1)$	14	0.14	0.65	0.45	0.26	1.00	-0.53	0.50	0.45
$RQ(t)$	15	0.05	-0.44	-0.15	-0.63	-0.53	1.00	-0.20	-0.24
$Q(t)$	16	0.09	0.55	0.61	0.25	0.50	-0.20	1.00	0.53
$(K(t)+U(t))$	17	0.11	0.93	0.98	0.50	0.45	-0.24	0.53	1.00

Appendix 12.

Semi-annual data used in model estimations (1960/1-1982/1)

Symbols of table A7 and units of the variables

symbol	variable name	unit
XSD	Sales (=purchases) of sawlogs from private nonindustrial forests....	$1000M^3$/semi-year
PXN	Nominal sawlog stumpage price.........	FIM/M^3
PX	Real stumpage price (deflated with whole sale price index, 1977/2=100)....	FIM/M^3
YDB	After tax income of Finnish households, nominal prices........................	FIM/semi-year
RCA	Marginal rate of interest on Central Bank debt..............................	%
VM	Export sales of sawnwood..............	$1000M^3$/semi-year
PYN	Nominal export unit value of sawnwood..	FIM/M^3
PY	Real export unit value of sawnwood (deflated with whole sale price index, 1977/2=100)...........................	FIM/M^3
Y	Production of sawnwood................	$1000M^3$/semi-year
IAI	Aggregated stocks of sawlogs..........	index
MH	Commercial fellings of sawlogs.........	$1000M^3$/semi-year
THI49	Whole sale price index.................	Index
D3	Timber price agreement dummy...........	0,1

The observation of sawlog stocks 1963/2, 1964/2, 1965/1 and 1965/2 have been adjusted according the sales and commercial fellings statistics.

Timber price agreement dummy is 1 also in the felling season 1978/79, although no price agreement for the whole country existed that year.

appendix 12. continued

Table A7. Semiannual data used in estmations.

	XSD	MH	PXN	PX	YDB	RCA
1960/1	2420.0	11486.4	22.2	79.0	4837.0	..
1960/2	6260.0	3392.6	25.5	89.7	5198.0	22.66
1961/1	2035.0	10445.2	29.6	103.5	5584.6	12.33
1961/2	4718.0	2724.8	29.9	105.3	5821.9	14.18
1962/1	1762.0	9615.6	25.8	89.3	6057.2	22.45
1962/2	4646.0	2807.4	26.6	91.4	6259.4	27.31
1963/1	2243.0	10102.0	27.6	93.4	6508.8	21.09
1963/2	5572.0	3213.0	32.3	106.4	6846.5	19.72
1964/1	2337.0	11676.9	32.9	103.7	7455.3	16.51
1964/2	5678.0	3193.1	38.9	118.2	7671.5	20.64
1965/1	2578.0	13116.1	38.5	114.5	8069.8	7.00
1965/2	4426.0	1647.9	36.4	108.0	8454.6	7.00
1966/1	2106.0	9934.7	36.2	106.0	8590.1	9.61
1966/2	5257.0	2341.3	33.5	97.0	9329.4	29.42
1967/1	1850.0	9988.1	30.4	87.5	9532.6	9.98
1967/2	4534.0	2631.9	28.2	78.4	9617.4	11.24
1968/1	2072.0	10234.2	28.0	72.1	10357.6	8.30
1968/2	7882.0	3893.8	32.0	80.6	10807.6	7.00
1969/1	2374.0	11747.9	31.5	78.3	11553.5	7.00
1969/2	10097.0	3993.1	36.4	88.8	12301.1	7.23
1970/1	2784.0	12755.9	36.3	86.1	12831.0	12.46
1970/2	10344.0	5116.1	42.7	100.3	13417.9	23.19
1971/1	2410.0	12430.5	41.5	94.5	13884.3	10.39
1971/2	6643.0	4021.5	52.8	116.9	15041.4	9.12
1972/1	2550.0	10482.9	40.2	85.2	16321.0	7.75
1972/2	9587.0	5063.1	45.0	91.2	17500.1	7.75
1973/1	3605.0	11051.8	49.2	92.1	18700.1	7.75
1973/2	12890.0	6017.2	106.4	177.2	20703.9	18.02
1974/1	3193.0	12545.6	108.0	160.0	22894.9	17.14
1974/2	7775.0	4924.4	113.1	153.8	26177.6	12.09
1975/1	1738.0	8503.8	103.0	130.7	27770.4	16.52
1975/2	2110.0	2800.2	84.3	103.5	31426.6	22.75
1976/1	2595.0	6325.3	94.8	110.0	31627.2	19.51
1976/2	7301.0	5104.7	110.3	119.5	35087.7	17.76
1977/1	2363.0	8382.0	104.4	107.3	36400.2	15.83
1977/2	7036.0	5222.0	96.9	96.9	37124.4	18.90
1978/1	3688.0	9379.6	106.4	104.3	40999.4	14.10
1978/2	12166.0	6459.6	102.5	97.4	41425.1	9.41
1979/1	4685.0	13410.3	104.8	95.9	45123.6	8.38
1979/2	12467.0	6475.6	119.5	102.8	48336.3	10.15
1980/1	4810.0	11485.4	122.2	96.6	51389.7	13.44
1980/2	11072.6	7862.4	153.4	112.9	56224.4	15.73
1981/1	2246.6	11329.2	165.1	113.6	58671.2	15.76
1981/2	6653.3	7166.0	166.6	109.2	61846.8	14.16
1982/1	2235.3	10838.0	170.1	107.8	..	..
1982/2	..	7180.0	..	..	..	..

	VM	PYN	PY	Y	IAI	THI49	D3
1960/1	1831.0	115.0	408.8	3462.1	0.97	197.2	0.0
1960/2	2854.6	121.3	426.8	2896.8	1.00	199.3	0.0
1961/1	1892.2	124.7	436.1	3303.2	0.93	200.5	0.0
1961/2	1822.1	122.5	430.9	2793.8	0.85	199.3	0.0
1962/1	2232.2	117.8	407.9	2876.5	0.76	202.5	0.0
1962/2	3120.9	118.7	408.1	2426.2	0.66	204.0	0.0
1963/1	1854.8	121.4	411.4	2788.7	0.78	206.8	0.0
1963/2	3104.5	123.2	405.6	2537.8	0.94	213.0	0.0
1964/1	1652.5	130.5	411.4	3076.0	0.90	222.3	0.0
1964/2	2927.0	136.2	414.1	2646.6	0.96	230.7	0.0
1965/1	1191.8	148.6	442.2	3023.3	0.89	235.7	0.0
1965/2	1849.6	153.3	454.9	2514.5	0.83	236.3	0.0
1966/1	1667.9	150.2	439.8	2642.5	0.72	239.5	0.0
1966/2	1371.2	148.6	430.4	2145.8	0.91	242.2	0.0
1967/1	2034.7	142.1	408.5	2562.2	0.75	243.8	0.0
1967/2	1749.7	151.2	419.7	2138.4	0.82	252.7	0.0
1968/1	2261.2	169.2	435.0	2593.0	0.66	272.7	0.0
1968/2	2749.5	174.2	439.4	2289.2	1.02	278.0	0.0
1969/1	1798.7	183.3	456.1	2966.8	0.82	281.8	0.0
1969/2	2484.7	186.5	454.4	2569.6	1.33	287.8	0.0
1970/1	2082.0	195.4	463.0	3354.6	1.42	295.8	0.0
1970/2	2655.0	197.3	463.2	2910.6	1.54	298.7	0.0
1971/1	1911.0	206.3	469.7	3391.6	1.28	308.0	0.0
1971/2	2157.0	208.7	462.4	2873.2	1.13	316.5	0.0
1972/1	2922.0	216.5	458.9	3317.1	0.95	330.8	0.0
1972/2	3720.0	208.1	421.7	2733.3	1.40	346.0	0.0
1973/1	1810.0	236.4	442.5	3569.3	1.19	374.5	0.0
1973/2	4059.0	303.6	505.6	3008.8	2.35	421.0	0.0
1974/1	554.0	455.4	674.3	3783.0	1.59	473.5	0.0
1974/2	220.0	539.2	733.1	2604.0	1.65	515.7	0.0
1975/1	947.0	489.6	621.2	2680.0	1.36	552.7	0.0
1975/2	2123.0	373.5	458.6	1678.0	1.09	571.2	0.0
1976/1	2023.0	396.0	459.4	2742.0	1.02	604.3	0.0
1976/2	1660.0	479.8	520.0	2456.0	1.33	647.0	0.0
1977/1	2158.0	547.7	562.9	3464.0	1.12	682.2	0.0
1977/2	2152.0	543.5	543.5	2805.0	1.22	701.2	0.0
1978/1	2679.0	528.9	518.5	3688.0	0.99	715.3	0.0
1978/2	3732.0	537.0	510.3	2952.0	1.73	737.8	1.0
1979/1	2904.0	569.2	520.6	4392.0	1.41	766.7	1.0
1979/2	3930.0	602.3	517.7	3544.0	1.98	815.7	1.0
1980/1	2086.0	678.2	536.3	4743.0	1.54	886.7	1.0
1980/2	1179.0	749.3	552.0	3711.0	1.97	951.8	1.0
1981/1	1682.0	775.0	526.3	4167.0	1.49	1019.0	1.0
1981/2	1838.0	677.7	438.7	3132.0	1.60	1068.5	1.0
1982/1	1543.0	646.9	404.7	3311.0	1.34	1106.2	1.0
1982/2	1879.0	725.7	440.9	3066.0	..	1138.7	1.0

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Kansantaloudellisen metsäekonomian tutkimussuunta

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