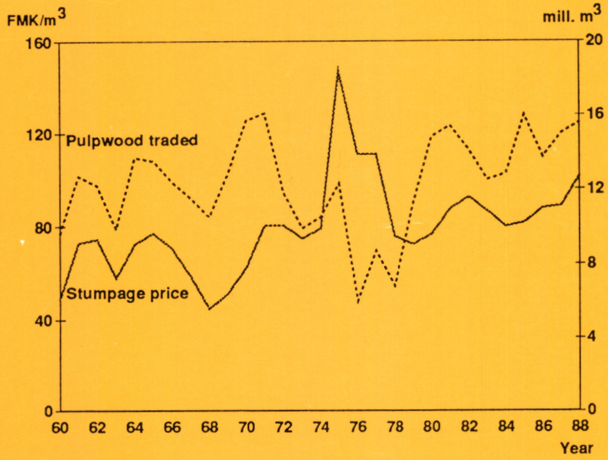
LAURI HETEMÄKI
JARI KUULUVAINEN

ESTIMATING SUPPLY AND DEMAND FOR ROUNDWOOD:

How to incorporate the data and theory?



METSÄNTUTKIMUSLAITOKSEN
TIEDONANTOJA 397

Metsäekonomian tutkimusosasto

Finnish Forest Research Institute
Department of Forest Economics

METSÄNTUTKIMUSLAITOS
THE FINNISH FOREST RESEARCH INSTITUTE

Osoite: Unioninkatu 40 A
00170 Helsinki
Puhelin: (90) 857 051
Telefax: (90) 625 308
Telex: 121286 metla sf

Address: Unioninkatu 40 A
SF-00170 Helsinki
Finland
Phone: +358 0 857 051
Telefax: +358 0 625 308
Telex: 121286 metla sf

Ylijohtaja: Eljas Pohtila
Director:

Tutkimusjohtajat: Eero Paavilainen, Jari Parviainen, Risto Seppälä
Research directors:

Metsäntutkimuslaitos on maa- ja metsätalousministeriön alainen vuonna 1917 perustettu valtion tutkimuslaitos. Sen päätehtävänä on Suomen metsätaloutta sekä metsävarojen ja metsien tarkoituksenmukaista käyttöä edistävä tutkimus. Metsäntutkimustyötä tehdään lähes 800 hengen voimin kolmella tutkimusosastolla ja kymmenellä tutkimus- ja koeasemalla. Tutkimus- ja koetoimintaa varten laitoksella on hallinnassaan valtionmetsiä yhteensä noin 150 000 hehtaaria, jotka on jaettu 17 tutkimusalueeseen ja joihin sisältyy kaksi kansallis- ja viisi luonnonpuistoa. Kenttäkokeita on käynnissä maan kaikissa osissa.

The Finnish Forest Research Institute, established in 1917, is a state research institution subordinated to the Ministry of Agriculture and Forestry. Its main task is to carry out research work to support the development of forestry and the expedient use of forest resources and forests. The work is carried out by means of 800 persons in three research departments and ten research and field stations. The institute administers state-owned forests of over 150 000 hectares for research purposes, including two national parks and five strict nature reserves. Field experiments are in progress in all parts of the country.

Metsäntutkimuslaitoksen, Metsäekonomian tutkimusosaston tiedonantoja 397

Finnish Forest Research Institute, Department of Forest Economics, Working Paper 397

ESTIMATING SUPPLY AND DEMAND FOR ROUNDWOOD: HOW TO INCORPORATE THE DATA AND THEORY ?

Lauri Hetemäki and Jari Kuuluvainen

Helsinki 1991

ABSTRACT

This paper examines the aggregate pulpwood market in Finland using the econometric approach advocated by Hendry et al. (1988) and Spanos (1990) who propose a statistically consistent way to estimate simultaneous-equations models. The effects of capital market imperfections on private nonindustrial timber supply are allowed and a three-input demand function is used (capital, labour and wood). By comparing the results with an earlier model specification of the Finnish pulpwood market, it is concluded that the new approach provides statistically more robust and informative results than the earlier specification. The results indicate that short-term supply reacts positively to an increase in stumpage price, while the long-run (total) elasticity is negative and rather small in absolute terms. The short-term elasticity of demand with respect to the stumpage price is positive and the long-run elasticity is negative. Capital is a complement while labor is a substitute for roundwood input. The dynamic adjustment process, substitution and cross-price effects and the capital market imperfections implied by the present study differ from the results obtained in previous studies.

Key words: roundwood markets, simultaneous equations model, statistical validity

Authors' address: The Finnish Forest Research Institute, Box 37, SF-00381 Helsinki, Finland

ISBN 951 - 40 - 1187 - 2
ISSN 0358 - 4283

HAKAPAINO OY, HELSINKI 1992

CONTENTS

PREFACE

The present study was conducted at the Department of Forest Economics of the Finnish Forest Research Institute. The study originates from the meetings of an informal "econometric study group" at the Department of Forest Economics. The work of this group led to the construction and estimation of an econometric model for the Finnish roundwood market (Kuuluvainen et al. 1988). In the present study, the pulpwood market part of the model reported in Kuuluvainen et al. (1988) is further developed using the recent advances in time series econometrics. An abridged version of this report is presented in Hetemäki and Kuuluvainen (forthcoming).

The authors gratefully acknowledge helpful comments from Darius Adams, David Newman, and Ville Ovaskainen. We also want to express our gratitude to the late Jorma Salo for the valuable contributions to Finnish roundwood market studies. Finally, we would like to thank all the researchers who took part in the work of the econometric study group for the enthusiastic and inspiring, although occasionally long and exhaustive, discussions on the subject. The first author acknowledges financial support from the Academy of Finland.

Lauri Hetemäki and Jari Kuuluvainen

1. INTRODUCTION

Econometric analyses of roundwood and forest product markets based on time series data have a relatively long tradition. Since the pioneering study by McKillop (1969), a number of studies have appeared in the USA (e.g., Robinson 1974, Adams & Haynes 1980 and Newman 1987) and in Scandinavia (e.g., Brännlund, Johansson and Löfgren 1985, Kuuluvainen 1986, Kuuluvainen et al. 1988 and Hultkranz and Aronsson 1989). These studies have greatly increased our understanding of the basic relationships affecting roundwood markets. However, recent developments in time series econometrics and simultaneous equations estimation (Engle and Granger 1987, Hendry et al. 1988, Phillips and Durlauf 1986, Spanos 1990) can provide new insights into these markets. For example, assumptions made in earlier studies concerning short-term dynamics, substitution and cross-price effects, and the effects of capital market imperfections on nonindustrial private wood supply can now be examined in a more systematic way.

The purpose of this paper is to provide new evidence on the functioning of the pulpwood market in Finland. However, the study should also be of interest for empirical applications of small simultaneous equations systems in general. We apply recent advances in time series econometrics and simultaneous equations system estimation, as proposed by Hendry et al. (1988) and Spanos (1990) (hereafter the HS approach), to estimate the demand for and supply of pulpwood using annual data from 1960 to 1988. The results are compared with an earlier specification of the pulpwood market (Kuuluvainen et al. 1988) which we re-estimate and examine using a number of tests and evaluation criteria not previously used in roundwood market studies.

The results reveal misspecification problems in Kuuluvainen et al., while the new specification is found to be statistically consistent and more informative. As a result, the robustness of short-term forecasts for the pulpwood market are improved. Further, the new model implies revisions of some of the hypotheses concerning the behavioral functioning of the pulpwood market.

The remainder of the paper provides a description of the theoretical framework, the empirical results and discussion of their implications. The variables and data are described in the Appendix.

2. THEORETICAL MODEL

2.1 Supply of Pulpwood

Nonindustrial private forest (NIPF) owners are the main suppliers of raw material to the forest-based industries in Finland. The institutional framework of the Finnish pulpwood market has been described in Kuuluvainen et al. and we do not repeat the discussion here. The empirical evidence from the Finnish data indicates that market imperfections affect the timber supply behavior of NIPF owners (Kuuluvainen & Salo). If uncertainty (cf. Koskela, 1989a,b), imperfect capital markets (cf. Kuuluvainen, 1990), and/or nontimber values (cf. Binkley) are assumed, optimal timber supply and consumption must be decided simultaneously. Therefore, the variables which affect the optimal consumption decisions also affect the optimal harvesting decisions. Using a two period Fisherian consumption-savings model for determining the optimal harvesting decisions under selective credit rationing, the behavioral supply equation becomes (Kuuluvainen, 1990),

$$(1)\quad Q_t^s = Q^s(\underset{+/-}{P_t}, \underset{-/+}{P_{t+1}}, \underset{-}{R_{t+1}}, \underset{+}{V_t}, \underset{-}{I_t}, \underset{+}{I_{t+1}}, \underset{-}{\bar{B}_t}, \underset{+}{\delta}),$$

where P_i is the pulpwood price, net of harvesting costs (i = t, t+1), R_{t+1} is the market interest rate, V_t is the stock of growing merchantable timber, I_i is the exogenous nonforestry income (i=t,t+1), $\bar{B}$ is the exogenous credit limit faced by an individual forest owner, δ is the subjective rate of time preference.

Under selective credit rationing, the effects of prices and the interest rate cannot be determined a priori. The price effect of the credit-rationed forest owner contains both the positive substitution effect and the negative income effect. The sign of the interest rate is undetermined as some forest owners face restrictions in the capital market and others do not. For the credit-rationed suppliers the interest rate has only a negative (income) effect, while for the nonrationed ones the effect is unambiguously positive. Note that the implications of other types of market imperfections for the empirical analysis of pulpwood supply are fairly similar to those of selective credit rationing. The essential point is that, in the presence of market imperfections, the income level of forest owners also affects the supply. When aggregated data are used it is reasonable to assume that credit rationing faced by individual forest owners as well as the subjective rate of time preference do not have a systematic pattern over time. Furthermore, it is not generally possible to measure these variables in aggregated data. Consequently, they are not included in the empirical analysis. Finally, due to data problems, allowable drain series is used to approximate the stock of growing timber (see Appendix).

2.2 Demand for Pulpwood

The paper industry's output can be described using the production function

$$(2) \quad Y_t = F(K, L, Q)$$

where K is capital input, L is labour input and Q is the wood raw-material input needed to produce an amount Y_t of the final product. In eq. (2) it is implicitly assumed that the K, L and Q inputs are weakly separable as a group from the residual inputs (materials and energy). Firms in the pulp and paper industry are assumed to sell their final products on competitive export markets at given prices, PX_t. Ignoring decisions on the holding of raw-material inventories and the uncertainty contained in short-term production decisions, the profit-maximizing problem of the representative firm can be used to derive the short-term demand function for pulpwood (cf. Brännlund et al. 1985):

$$(3) \quad Q_t^d = Q^d\,(\underset{+}{PX_t},\ \underset{-}{P_t},\ \underset{?}{W_t},\ \underset{?}{C_t}),$$

where Q_t^d is the demand for pulpwood, PX_t is the export price of final products, P_t is the stumpage price, W_t is the unit labour cost, and C_t is the price of capital. The effects of wages and capital are uncertain because it cannot be deduced a priori whether roundwood is a technical complement or a substitute for these inputs.

3. RESEARCH RESULTS

3.1 Properties of the Time Series

Depending on the particular properties of the time series used for estimation, different modelling strategies must be chosen. For example, the "error correction" or "cointegration" models have become popular for analyzing nonstationary time series data (see, e.g., Engle and Granger 1987, Hendry and Ericsson 1991). Further, for the validity of statistical inference it is important to know whether the series are stationary or not (see, e.g., Phillips 1986 and Phillips and Durlauf 1986). In order to examine the properties of the data series, the autocorrelation functions and autoregressive processes of the series were computed and normality and stationarity tests performed.

All the series are logarithmic transformations of the original series and the monetary series are deflated (see the Appendix for data description). The results in Table 1 show that the first autocorrelation coefficient is rather high and decreases slowly with increases in lags for the user cost (C_t), wages (W_t), exogenous income (I_t) and allowable drain (V_t) series, indicating that the levels of these series are not stationary. However, their first differences appear to be stationary, and consequently these series can be regarded as I(1) series according to the autocorrelation functions. All the other series used in the models appear to be I(0) series. The results (Table 1) of the regression of each of the levels series on their respective five lags indicated that all the series follow a first-order autoregressive process (i.e. AR(1) process).

Table 1. Time Series Properties of the Data.

Series	Autocorrelation function					Autoregressive process				
lag	1	2	3	4	5	1	2	3	4	5
Pulpwood quantity										
Q_t	.48	.27	.03	-.06	-.07	.54*	.13	-.24	.06	.00
ΔQ_t	-.30	-.03	-.21	-.01	-.09					
Stumpage price										
P_t	.64	.35	.17	.15	.18	.82*	-.06	-.35	.31	-.01
ΔP_t	-.05	-.16	-.33	.01	.17					
Export price										
PX_t	.76	.53	.45	.44	.33	.08*	-.27	.15	.16	-.11
ΔPX_t	-.01	-.34	-.12	.17	.16					
User cost										
C_t	.90	.81	.82	.80	.72	.74*	-.43	.46	.01	.02
ΔC_t	-.05	-.47	.08	.22	-.06					
Wages										
W_t	.96	.94	.92	.93	.95	.74*	-.16	-.08	.15	.24
ΔW_t	-.30	-.05	-.22	-.04	.13					
Interest rate										
R_t	.62	.26	.06	.03	-.01	.76*	-.20	.01	.03	-.03
ΔR_t	-.05	-.27	-.15	-.01	-.15					
Disposable income										
I_t	.99	.99	.98	.98	.97	.71*	-.46	.79	-.54	.41
ΔI_t	-.15	-.16	.16	-.01	-.22					
Allowable drain										
V_t	.97	.94	.89	.85	.80	.97*	.12	-.13	-.06	.11
ΔV_t	-.06	.04	-.09	-.09	.03					

Notes: In Table 1, * indicates significant t-values at the 5 % significance level for the autoregressive coefficients and Δ denotes the difference operator. All monetary units and the interest rate are deflated.

In Table 2 the results of the Jarque-Bera normality test (χ^2_N~ test) and the Dickey-Fuller (DF) and Durbin-Watson (CRDW) unit root tests are presented (for a description of the test statistics, see Hendry, 1989, and Engle & Granger 1987). Since the graphs of the series (and their distribution functions) indicated that there have been one-time changes in the structure of the series (as a result of the devaluation in 1967 and the severe recession after the oil crisis in 1973), we also use the modified Dickey-Fuller test, denoted by DF*, suggested by Perron (1989). The CRDW and DF tests are valid, since the results indicated that all the series follow the AR(1) process as required. However, it should be borne in mind that small sample bias may be present.

The results in Table 2 indicate that all the series, except Q_t, are normally distributed. The non-normality of the Q_t series is due to the significant outliers in the sample in 1976 and 1978. According to the DF and CRDW test, the Q_t series follows a I(0) process, the P_t series being just below the 5 percent critical value, while all the other series are clearly nonstationary. However, the DF* test shows that if the one-time changes are filtered out and a time trend included, all the series, except the W_t and V_t series, are I(0).[1]

The above results indicate that the nonstationarity, apparent in many expanding roundwood markets (cf. Brännlund et al. 1985 and Newman 1987), is not a problem in the pulpwood market in Finland. Therefore, for the data used in the present study, cointegration models are not relevant for modelling the supply of and demand for pulpwood (Engle and Granger 1987).[2] Further, tests on W_t and C_t series, on the one hand, and on V_t and I_t, on the other, indicated that although the series themselves are I(1), their linear combinations are stationary (i.e., they are cointegrated).[3] Therefore, the ordinary least squares (OLS) estimates of these variables are (*super*) consistent, but their distributions are not normal.

Table 2. Normality Test (χ^2_N) and Unit Root Tests (DF, DF*, CRDW)

Series	χ^2_N	DF	DF*	CRDW
Pulpwood quantity Q_t	7.64	-3.00	-6.20	1.00
Stumpage price P_t	0.35	-2.70	-9.10	0.67
Export price PX_t	0.75	-1.79	-5.50	0.47
User cost C_t	2.45	-1.66	-5.40	0.22
Wages W_t	2.20	-1.49	-3.30	0.10
Bank lending rate R_t	4.16	-2.37	-5.00	0.73
Disposable income I_t	1.62	-2.31	-	0.04
Allowable drain V_t	1.53	-0.18	-2.20	0.07

Notes: Critical value for DF test at 5% significance level and 25 observations is 3.00 (Fuller 1976); for DF* test critical values vary between -3.68 and -3.80 (Perron 1989). Critical value for CRDW -test at 5% significance level and 30 observations is 0.79 (Bhargava 1986). Critical value for χ^2 -test at 5% level and 2 degrees of freedom is 5.99. I_t does not have significant outliers and DF* test was not computed for it.

3.2 Specification and Estimation of the Statistical and Econometric Model

Following Hendry et al. (1988) and Spanos (1990), we draw a distinction between the *statistical* model (the system or reduced form) and the *econometric model* of the system. The statistical model is defined by the set of variables of interest (suggested by economic theory), their status (classification into modelled and nonmodelled variables) and the lag polynomials involved. The statistical model summarizes the sample information and ensures that the statistical assumptions underlying the model are valid for the data used. If the system is not statistically valid, there is little point in imposing further restrictions on it, and tests thereof will be against an invalid baseline. Once the system has been found to be statistically *adequate*, the structural econometric model is derived by imposing zero restrictions, implied by the economic theory, on the reduced form. The validity of the structural econometric model is judged on the basis of the overidentifying restrictions and using diagnostic tests for misspecification.

The HS approach emphasizes statistical adequacy rather than the modeller's subjective decisions in the process of specifying a model. Consequently, the problem of "multiple hypotheses", i.e., too many structural models supporting the data, is tackled in a systematic way. Thus, in order to make structural models directly comparable, a common statistical model (reduced form) is *first* estimated and its statistical validity is checked. Second, the overidentifying restrictions implied by different theoretical hypotheses and their statistical validity can be tested. Finally, for the models which survive the first two stages, the selection is made in terms of parameter constancy, robustness and parsimony.

Below, we first formulate the statistical model, check its validity, then simplify it via parameter restrictions in order to specify the structural econometric equations and test the resulting econometric model.

3.3 Statistical Model

Theoretical supply and demand equations (eqs. (1) and (3)) determine the basic variables to be included in the statistical model, but the dynamics is dictated by the data. Even in the case of a "two-period" theoretical pulpwood supply equation, it is not possible to derive, *a priori*, the explicit adjustment process. The theory behind roundwood supply and demand does not yet specify how quickly agents react to changes in prices and the choice of expectations structure (static, rational, adaptive, etc.), a priori, is ad hoc. We make no a priori assumptions about the dynamic behavior and consequently the role of expectations in the model is not addressed explicitly. Short-run dynamics is determined solely by the data.

To take into account short-term dynamics, lagged variables are included. Because of the small sample size and the large number of variables in the system, only a limited number of lags can be introduced simultaneously. Based on the experiments with different lag structures, a system consisting of eq.(4) and eq. (5) was found to be (on the basis of the test criteria reported in Table 3) statistically the most adequate summary of the sample information. The estimation results are shown in Table 3. Because the reduced form is a statistical summary of sample information, parsimony is not required at this stage and the model is deliberately overparameterized,

$$(4)\quad P_t = \alpha_0 + \alpha_1 Q_{t-1} + \alpha_2 Q_{t-2} + \alpha_3 P_{t-1} + \alpha_4 PX_t + \alpha_5 R_t + \alpha_6 R_{t-1} + \alpha_7 I_t + \alpha_8 V_t + \alpha_9 W_t + \alpha_{10} C_t + \mu_t$$

$$(5)\quad Q_t = \beta_0 + \beta_1 Q_{t-1} + \beta_2 Q_{t-2} + \beta_3 P_{t-1} + \beta_4 PX_t + \beta_5 R_t + \beta_6 R_{t-1} + \beta_7 I_t + \beta_8 V_t + \beta_9 W_t + \beta_{10} C_t + \varepsilon_t.$$

When estimated using *Ordinary Least Squares (OLS)*, eq.(4) and eq. (5) passed all the tests concerning the classical assumptions of a linear regression model (see Table 3). However, due to the small sample size, the precise estimation of parameters is not possible.

3.4 Econometric Model

The structural supply equation was derived by imposing zero restrictions implied by eq. (1) on eq. (4). Similarly, to obtain a demand equation, we imposed zero restrictions suggested by eq. (3) on eq. (5).[4] It turned out that we were unable to find a statistically valid demand equation when the export price (PX_t) was included *explicitly* in the structural model.[5] The high collinearity of the real export price and the real stumpage price indicates that fluctuations in export prices are transmitted to stumpage prices (c.f., Forsman & Heinonen 1989). Because the demand equation is homogeneous of degree zero in product and factor prices, one of the prices can be factored out. We used the production price index in the demand equation as a proxy for the price of the "other inputs" (i.e., energy and residual materials) and the export price, and consequently, as a deflator.[6] Since the production price index turned out to be almost identical to the nominal export price series, the information of the export price is included in the model, although we are not able to obtain an estimate for the elasticity of demand with respect to the export price.

On the basis of different diagnostic tests (shown in Table 4 and 5), the most satisfactory representation of the data proved to be the structural model shown in eq. (6) and eq. (7)

$$(6)\quad Q_t^s = \alpha_0 + \alpha_1 P_t + \alpha_2 P_{t-1} + \alpha_3 I_t + \alpha_4 V_t + \alpha_5 \Delta R_t + \alpha_6 \Delta Q_{t-1} + \varepsilon_t$$

$$(7)\quad Q_t^d = \beta_0 + \beta_1 P_t + \beta_2 P_{t-1} + \beta_3 W_t + \beta_4 C_t + \beta_5 Q_{t-1} + \mu_t,$$

where α_o and β_0 denote the constant terms. It may be noted that both the supply and demand equations include variables that are I(1) series. However, since I_t and V_t series are cointegrated in eq.(6), as are the W_t and C_t series in eq.(7), the parameter estimates of these series are *super consistent* in large samples, although the distribution of their t-values is nonstandard (Fuller 1976, Engle and Granger 1987).

Eqs. (6) and (7) were estimated using OLS, *recursive least squares (RLS)*, *two-stage least squares (2SLS)* and *three-stage least squares (3SLS)* estimation methods. However, since the 3SLS estimation results did not differ significantly from the 2SLS results, we only report the latter.

Table 3.The Estimated OLS Results for the Reduced Form Equations (Statistical Model), 1960-1988.

Independent variable	Pulpwood price, P_t	Quantity traded, Q_t
Constant	-8.14	-9.12
	(1.02)	(1.15)
P_{t-1}	0.42	-0.82
	(1.96)	(3.80)
Q_{t-1}	0.09	0.29
	(0.51)	(1.70)
Q_{t-2}	0.14	-0.11
	(0.78)	(0.59)
C_t	0.25	0.45
	(0.33)	(0.59)
W_t	-0.07	-0.33
	(0.18)	(0.88)
I_t	-0.27	-0.05
	(0.36)	(0.06)
R_t	0.01	0.01
	(0.96)	(0.33)
R_{t-1}	-0.01	-0.01
	(1.34)	(0.45)
V_t	0.66	3.06
	(0.28)	(1.32)
PX_t	1.35	0.34
	(2.12)	(0.53)

Model	RSS	R^2	DW	F_{RAC}	χ^2_N	F	F_c	F_{ARCH}
P_t	0.396	0.74	1.99	2.00	0.08	4.66	0.20	0.63
df.				3,13	2	10,16	1,15	3,10
Q_t	0.397	0.75	2.07	2.16	1.38	4.74	2.87	0.28
df.				3,13	2	10,16	1,15	3,10

Notes: df. denotes degrees of freedom. Symbols of test statistics are explained in the Appendix. t-statistics are in parentheses.

3.5 Results for the Supply Equation

The estimated results for the supply equation (6) are given in Table 4 (referred to as S1A and S1B). The re-estimation results of the pulpwood supply equation of Kuuluvainen et al., where

$$(8)\quad Q_t = \phi_0 + \phi_1 P_t + \phi_2 P_{t-1} + \phi_3 SP_t + \phi_4 Q_{t-1} + \phi_5 \Delta I_t + \pi_t,$$

are also reported (referred to as S2A and S2B) in Table 4. In eq. (8) adaptive pulpwood price expectations are assumed, the cross effect from the sawtimber stumpage price (SP_t) is included and the effect of disposable income is taken into account as the first difference.[7] The estimations of the Kuuluvainen et al. (1988) model were originally computed for the period 1965-1985 using 2SLS and a correction for autocorrelation. Here we have re-estimated it for the period 1960-1988 without the correction for autocorrelation.[8]

For eq. (6), the estimated parameters of the I(0) variables are statistically significant in the OLS estimations. The test result for the overidentification restrictions (χ^2_{OI}~ test) in the 2SLS estimations indicated that the restrictions imposed on the reduced form are valid. This implies that the structural model parsimoniously encompasses the unrestricted reduced form (see Hendry 1988). The parameter estimates are not very sensitive to the estimation method (OLS, 2SLS or 3SLS), except for the stumpage price variable. All the other coefficients are of similar magnitude and the t-values show that the 2SLS methods do not increase the efficiency of the parameter estimates, OLS estimation producing markedly higher t-values for some of the parameters (P_t, P_{t-1}, AD_t, ΔR_t). The endogeneity of stumpage price is rejected by the Granger causality test, which may be an indication that the differences in OLS estimation and 2SLS estimations are due to small sample bias in 2SLS.[9]

Table 4. Estimated Results for Supply of Pulpwood, 1960-1988.

Independent variable	S1A OLS	S1B 2SLS	S2A OLS	S2B 2SLS
Constant	-7.07	-7.42	3.26	2.00
	(4.16)	(3.75)	(2.72)	(1.85)
Pulpwood price, P_t	0.65	0.81	0.53	0.07
	(4.95)	(1.86)	(2.57)	(0.17)
Lagged pulpwood	-1.00	-1.07	-0.82	-0.61
price, P_{t-1}	(8.68)	(4.99))	(5.20)	(2.70)
Disp. income, I_t	-0.59	-0.68		
	(2.85)	(2.15)		
Δ Disp. income, ΔI_t			-0.40	
			(-0.19)	(0.49)
Allowable drain,	4.41	4.66		
V_t	(5.24)	(4.30))		
Lagged endogenous			0.44	0.49
variable, Q_{t-1}			(3.34)	(3.27)
Δ Lagged endog.	0.20	0.21		
variable, ΔQ_{t-1}	(2.46)	(2.38)		
Δ Interest rate,	-0.01	-0.02		
ΔR_t	(2.37)	(1.63)		
Sawtimber price,			-0.12	0.20
SP_t			(0.46)	(0.56)

Model	RSS	R^2	DW	F_{RAC}	χ^2_N	F	F_c	F_{ARCH}	F_F
S1A	0.205	0.85	1.94	0.33	1.20	22.32	1.33	0.23	0.66
df.				3,17	2	6,20	1,19	3,14	3,17
S2A	0.539	0.66	1.29	4.12	0.33	8.49	7.54	0.17	0.96
df.				3,19	2	5,22	1,20	3,16	3,19

Model	RSS	χ^2_I	DW	χ^2_{RAC}	χ^2_N	$\chi^2_{a=0}$	χ^2_{OI}	F_{ARCH}	χ^2_F
S1B	0.221	0.44	1.80	0.11	0.854	2188	8.466	0.05	1.19
df.		(2)/2		(3)/3	2	(7)/7	5	3,14	(3)/3
S2B	0.663	5.29	1.60	4.09	0.49	968	32.46	0.45	1.84
df.		(2)/2		(3)/3	2	(6)/6	4	3,16	(3)/3

Notes: df. denotes degrees of freedom. Symbols of test statistics are explained in the Appendix. t-statistics are in parentheses. Due to the different estimation method A and B models have different test statistics.

Comparing the OLS estimation results of the two different modelling approaches (Table 4), one can see that the new specification (S1A) has a better fit than the old specification (S2A). Furthermore, model S1A is a statistically valid representation of the data, while model S2A is not. Model S2A does not pass the F -test (F_{RAC}) for serially correlated errors, as also indicated by the low DW statistics. Kuuluvainen et al. used a correction for serial correlation, but the correct procedure would have been to re-specify the model. Furthermore, model S2A does not pass the test for correct functional form specification (F_c -test for linearity) and is overidentified (χ^2_{OI} -test).

The better performance of model S1A becomes more obvious when one looks at Figures 1-4. From Figure 1, which gives the actual and fitted values, one can see that model S2A systematically underpredicts the observed quantity traded during the 1980s (even after correction for autocorrelation, as can be seen from Kuuluvainen et al. 1988) and is, without dummy variables, unable to produce the turning points of the recession after the mid-1970s. Figure 2 shows the RLS estimates for the stumpage price coefficient, P_t, for both models. The plots make it possible to trace the evolution of P_t as more and more of the sample data are used in the estimation. Clearly, the P_t coefficient for S1A is more stable than for S2A. Figures 3 and 4 indicate that the standard error lines of the RLS estimates for the 1-step residuals for model S2A are more spread out ($\pm$ 0.3) than for model S1A ($\pm$ 0.2). Further, model S2A overpredicts the residual pattern for the period 1977-1988 more than does model S1A. The lower portion of the plots shows the probability values for those sample points where the hypothesis of parameter constancy would be rejected at the 5, 10 or 15 percent levels.

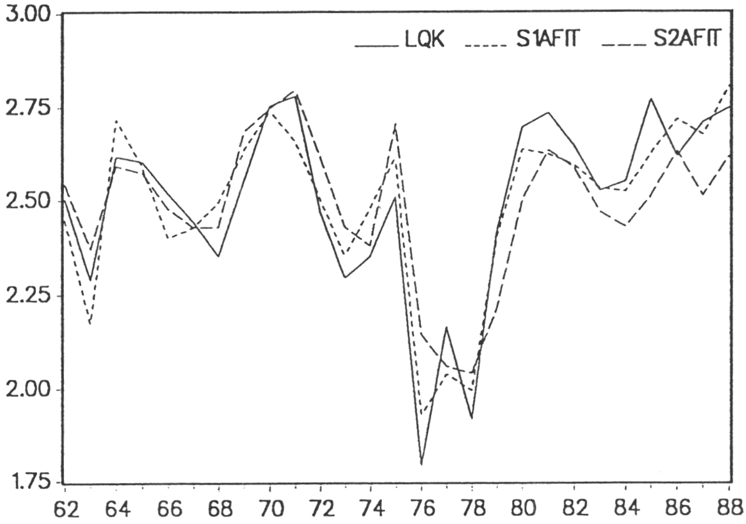


Figure 1. Actual and fitted values for S1A and S2a

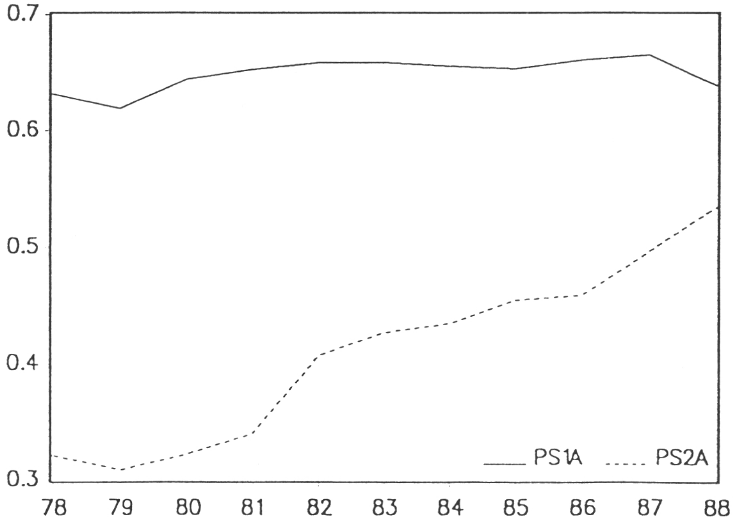


Figure 2. Recursive estimates for stumpage price coefficient

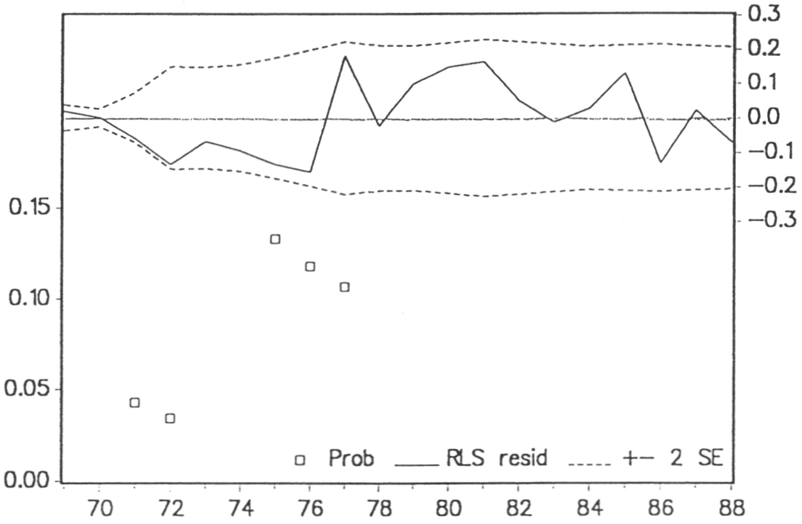


Figure 3. Recursive residuals for S1A

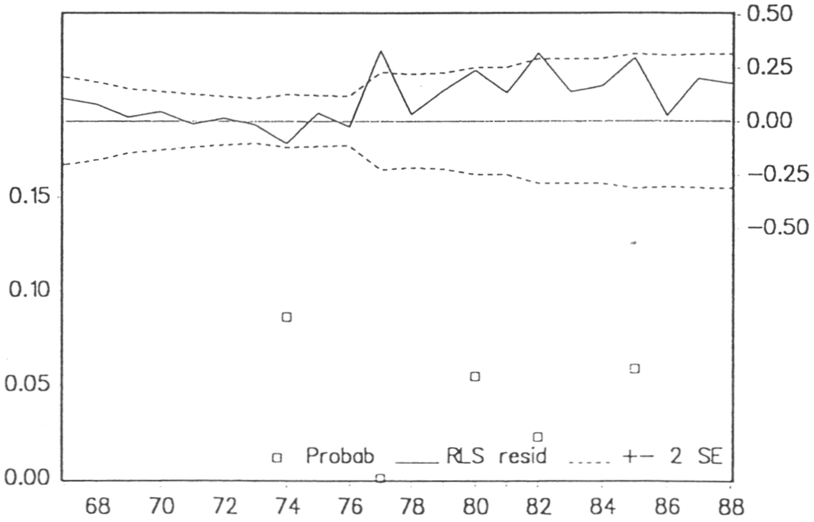


Figure 4. Recursive residuals for S2A

For the model S1A, the short-term supply reacts positively to an increase in the stumpage price (the elasticities are 0.64 for OLS and 0.81 for 2SLS). However, the long-term or total supply elasticity is negative and rather small in absolute terms (-0.36 for OLS and -0.27 for 2SLS).[10] The F-test for omitted variables (Hendry, 1989) suggests that the long-term effects of disposable income and annual allowable drain must be included. The elasticity of supply with respect to disposable income is -0.58, which is larger than the elasticities obtained from micro data (cf. Kuuluvainen & Salo 1991). The large elasticity for the allowable cut should not be interpreted as the elasticity of supply with respect to changes in the growing timber stock as the variable measures the aggregated annual increment of the stock. The coefficients of the difference of the real interest rate and the lagged endogenous variable capture short-term structural shocks. These variables do not seem to have long-term effects on timber supply as their levels (present or lagged) were rejected by the F-test for omitted variables when the difference terms were included. Although, the impact effect of the interest rate appears reasonable, as a major part of loans have not had fixed interest rates, it is difficult to judge whether the variable is related to inflationary expectations, to changes in monetary policy, or to some other factor.

The elasticities of stumpage prices in models S1A an S2A are not markedly different, but the dynamics implied by the two specifications are completely different. This is an important result if, for example, short-term forecasting is of interest. Furthermore, according to model S1A, disposable income seems to have a long-term effect on pulpwood supply, compared to the short term effect indicated by the old specification (note that the elasticity of the difference term in Kuuluvainen et al. (1988) was -23.7 when correction for serial correlation was used, hardly a realistic order of magnitude).

3.6 Results for the Demand Equation

As in the case of the supply equation, the estimated results for the demand equation (7) are compared to those obtained from re-estimating Kuuluvainen et al.'s (1988) demand equation,

$$(9)\ \ Q_t = \delta_0 + \delta_1 P_t + \delta_2 PX_t + \delta_3 Q_{t-1} + \delta_4 D75/76 + \delta_5 D78/79 + \eta_t\ ,$$

where D75/76 and D78/79 are dummy variables taking account of structural changes connected with export market developments after the energy crisis. The results from the OLS and 2SLS estimations of eqs. (7) and (9) are shown in Table 5 (referred to as D1A, B and D2A, B, respectively).

The results in Table 5 show that the new demand specification (D1A, B) has a better fit than the Kuuluvainen et al. (1988) specification (D2A, B). Model D1A passes all the diagnostic tests, while model D2A fails the test for correct functional form (F_c -test for linearity) and the low t-statistics indicates problems with the specification. In fact, the F_{ARCH} -test shows that heteroscedasticity is a problem for model D2A. When the heteroscedastic consistent standard errors (not reported here) are used to compute the t-values, only the estimate for the D77/78 dummy variable had a t-value above 2. Thus, model D2A is not a satisfactory representation of the data generation process. Although the diagnostic test results for 2SLS estimations of model 2 (i.e., D2B) indicate no significant problems with the specification, the test statistics are poorer than for model D1B. In particular, the residual sum of squares (RSS) is high, indicating high variance in the model. Furthermore, model D2B clearly failed to pass the overidentification test.

Table 5. Estimated Results for Demand for Pulpwood, 1960-1988.

Independent variable	D1A OLS	D1B 2SLS	D2A OLS	D2B 2SLS
Constant	3.83	4.54	-2.21	-6.96
	(5.34)	(4.84)	(0.69)	(1.48)
Pulpwood price,	0.43	0.14	0.39	-0.35
P_t	(3.21)	(0.49)	(1.87)	(0.77)
Export price,			0.36	1.29
PX_t			(0.80)	(1.76)
Lagged pulpwood	-0.92	-0.79		
price, P_{t-1}	(6.13)	(3.83)		
Lagged endogenous	0.35	0.36	0.09	0.30
variable, Q_{t-1}	(3.25)	(2.82)	(0.53)	(1.28)
User cost, C_t	-0.34	-0.24		
	(0.97)	(0.59)		
Wage, W_t	0.38	0.37		
	(2.48)	(2.10)		
D75/76			-0.69	-0.48
			(4.47)	(2.15)
D77/78			-0.59	-0.40
			(3.71)	(1.80)

Model	RSS	R^2	DW	F_{RAC}	χ^2_N	F	F_c	F_{ARCH}	F_F
D1A	0.34	0.78	1.64	1.15	1.71	15.70	3.18	0.15	0.67
df.				3,19	2	5,22	1,21	3,16	3,19
D2A	0.55	0.65	2.09	0.70	0.30	8.06	7.06	4.00	0.06
df.				3,19	2	5,22	1,21	3,16	3,19

Model	RSS	χ^2_I	DW	χ^2_{RAC}	χ^2_N	$\chi^2_{\alpha=0}$	χ^2_{OI}	F_{ARCH}	χ^2_F
D1B	0.42	1.99	1.80	0.95	2.21	140	8.46	0.33	0.65
df.		(3)/3		(3)/3	2	(6)/6	5	3,15	(3)/3
D2B	0.87	2.77	2.52	3.35	0.69	734	32.46	1.91	0.15
df.		(2)/2		(3)/3	2	(6)/6	4	3,16	(3)/3

Notes: df. denotes degrees of freedom. Symbols of test statistics are explained in the Appendix. t-statistics are in parentheses. Due to the different estimation method A and B models have different test statistics.

Figure 5 shows the actual and fitted values of the OLS estimations of the two models. The plots indicate that model D1A tracks the variations in the dependent variable better than does model D2A. However, model D1A fails to some degree to take account of the structural changes that occurred in 1976-1978 following the energy crisis. Owing to the dummy variables, model D2A does better in tracking the actual behavior during 1978-80. Figure 6 shows that for both models the estimated stumpage price coefficients are stable. Figures 7 and 8, which show the results from RLS estimations, indicate that, for the period 1978-1988, model D1A is somewhat more stable than D2A.

For model D1A, the short-run elasticity of demand with respect to the stumpage price is positive (0.43 for OLS and 0.14 and insignificant for 2SLS), while the long-run (total) elasticity is negative (-0.76 for OLS and -1.03 for 2SLS), as predicted by theory. The positivity of the short-run stumpage price parameter is not inconsistent with theory, since the theoretical model does not imply any specific short-term adjustment. The positive elasticity in the short run may be due to the correlation in the changes in the present period stumpage price and the export price, and/or to price expectations concerning the stumpage price and export price.

The OLS results for the Q_{t-1} parameter (0.36) show rather slow adjustment in the quantity demanded. The coefficient of the user cost is negative and that of the wage rate is positive, indicating that capital is a technical complement while labour is a technical substitute for roundwood input. The absolute values of the parameters are somewhat different in the OLS estimations from those obtained in 2SLS. In particular, the t-value for the stumpage price (P_t) is clearly not significant when 2SLS is used, while it is significant even at the 1 percent level if OLS is used.

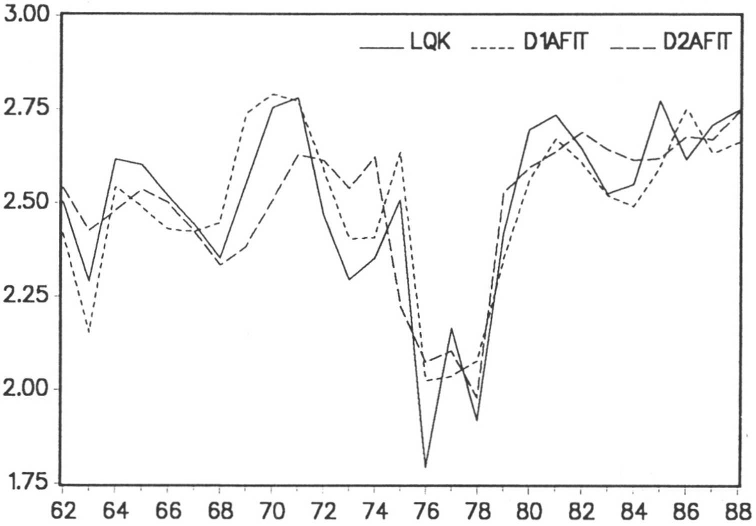


Figure 5. Actual and fitted values for D1A and D2A

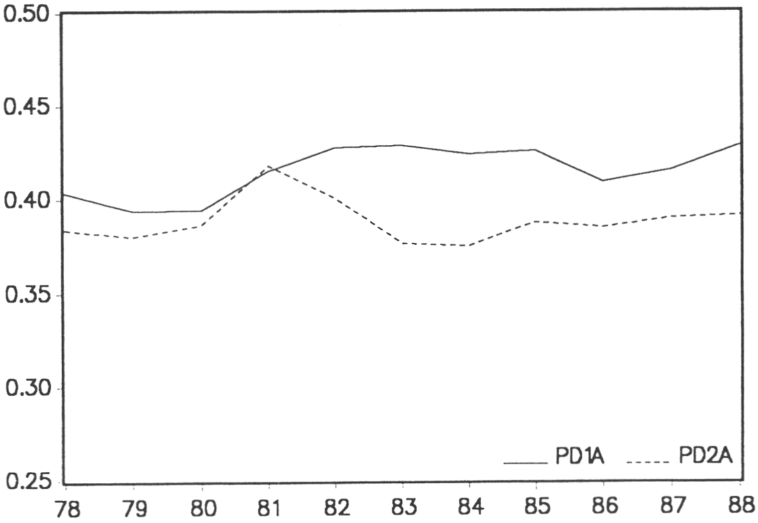


Figure 6. Recursive estimates for stumpage price coefficient

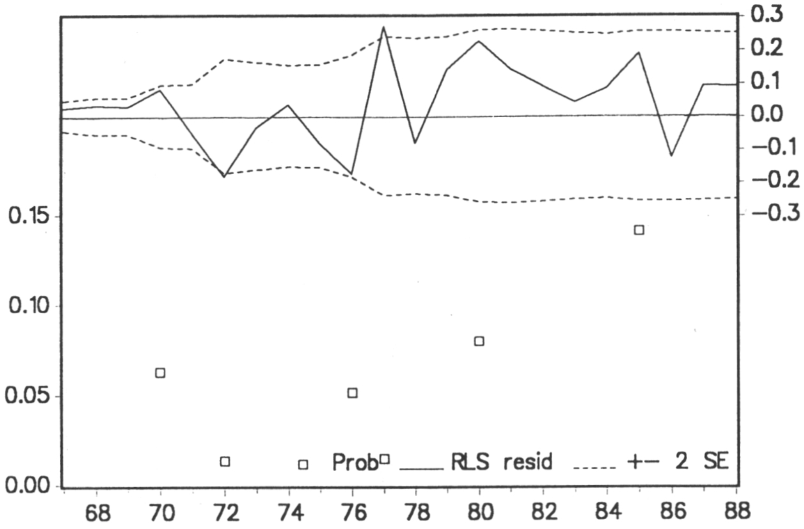


Figure 7. Recursive residuals for D1A

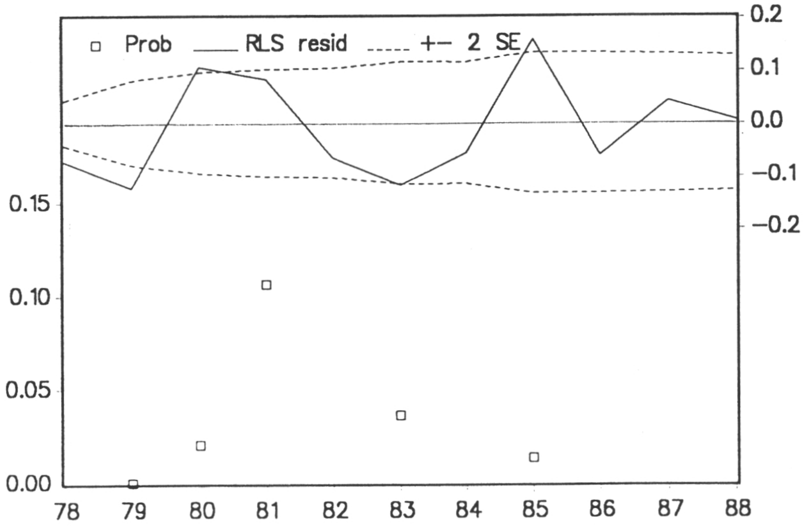


Figure 8. Recursive residuals for S2A

3.7 Encompassing

It is interesting to examine which equation(s) one should use if one is only interested in *forecasting* pulpwood prices and quantities. One criterion for accepting a model specification is whether it "encompasses" a rival model, i.e. whether it can account for or explain the results obtained by rivals. The encompassing tests test whether the variance of one model is dominated by the variance of another (Hendry 1988). In Table 6, we report the results of the encompassing tests for OLS supply and demand equations (models S1A and D2A).

The first column in Table 6 is the value of the statistics that S1A $\in$ D1A (read model S1A encompasses model D1A), followed by the form of the test and test statistics. The Cox test tests whether the residual variances of the two models are equal. The Ericsson IV test is the same as Cox, except that the endogenous explanatory variables are replaced by instrumental variables (fitted values), where the instruments are all the exogenous variables. The Sargan test is a Wald test of the restricted against the unrestricted reduced form and so it is a test of the validity of using D1A's instruments when estimating S1A (and conversely). Finally, the Joint model (F-) test is of each model against M_m (the linear combination of the two models), i.e. whether there is a more general formulation which encompasses both models, shown by the probability values. Hypothesis D1A $\in$ S1A is rejected by the Cox and Ericsson test statistics and also the Sargan test statistic is close to rejecting the hypothesis. Furthermore, S1A $\in$ M_m is rejected (the probability for acceptance is 0.052), which means that the demand equation does not contain the information included in the supply equation. On the other hand, according to the first column, the supply equation includes specific features not included in the demand equation (i.e., S1A $\in$ D1A is not rejected). Supply also seems to contain information on a more general formulation including the non-redundant regressors of both models (the reduced form), i.e. the simpler supply equation encompasses the less parsimonious model

Table 6. Encompassing Test for Supply (S1A) and Demand Equations (D1A).

Supply v. Demand	Form	Test	Form	Demand v. Suppy
-0.346	N(0,1)	Cox	N(0,1)	-5.302
(-1.96)				(-1.96)
0.292	N(0,1)	Ericsson IV	N(0,1)	3.407
(1.96)				(1.96)
0.868	$\chi^2(3)$	Sargan	$\chi^2(4)$	8.559
(7.81)				(9.49)
0.257	F(3,17)	Joint Model	(F(4,17)	2.924
(3.20)				(2.96)
[0.855]		Probability		[0.052]

(reduced form), M_m. Therefore, if one is only interested in forecasting short-term quantity or price fluctuations, the structural "supply" specification should be used. This result is interesting in that it is commonly recommended that in cases where only predictions are desired, the estimated reduced form coefficients should provide the basis for making those predictions (see, e.g., Judge et. al. 1985, p. 574).

4. CONCLUSIONS

We have examined a small dynamic simultaneous-equations model of the pulpwood market in Finland in the light of recent developments in time series econometrics and systems estimation. We applied the "Hendry and Spanos" approach, which to our knowledge has not been applied to roundwood market models before. The estimated model was shown to be statistically more robust and informative than the earlier specification (Kuuluvainen et al. 1988). In fact, careful re-examination of Kuuluvainen et al. showed that the model fails a number of tests concerning the assumptions of the classical linear regression model, is over-identified and does not produce statistically significant and stable parameter estimates for pulpwood demand. On the other hand, using the HS approach, we were able to find a statistically valid econometric specification which is derived from the theoretical model and is congruent with the underlying data generation process.

Although the results for the new model indicate that the short- and long-run stumpage price elasticities for supply are of the same order of magnitude as obtained by Kuuluvainen et al. (1988), the dynamic adjustment implied by our models are different. Using difference terms (impact effects), the structural shocks related to the severe recession in the mid-1970s can be explained reasonably well without using dummy variables. Furthermore, it turns out that a measure of the total volume of merchantable timber and the long-term effect of disposable income must be included in the supply equation (as also indicated by the theory). The cross-price effect of sawtimber, on the other hand, can be ignored (see footnote 7). For the demand function, the three-factor specification, which allows for substitution in production between the inputs, is supported by the data. Contrary to earlier findings, the stumpage price seems to have both a long-term effect and an impact effect on the demand for pulpwood. The long-term effect is negative, as predicted by the theory, while the short-term effect is positive and may be related to export price and/or stumpage price expectations.

We do not claim that the new model represents the "true" structural relationships in the pulpwood market. An econometric model is always just an approximation (reduction) of the underlying data generation process. In the present case, there are still several important problems related, for example, to the construction of the data series (e.g., do the observed prices and quantities traded represent the "equilibrium" values or the adjustment towards the "equilibrium"?) and to the small sample size. However, the HS approach offers a systematic framework for model-building and requires/provides much more information about the underlying DGP than previous roundwood market studies. Therefore, the need for detailed examination of the data and the testing of the statistical assumptions are emphasized while the role of the modeller's subjective decisions are de-emphasized. The application of this approach to roundwood markets (and other markets) is likely to generate new results which may change our previous views about the behavior of the markets, or confirm them, but with an increased statistical robustness, thereby improving, e.g., short-term forecasting properties.

FOOTNOTES

1. Because the I_t series does not have significant outliers the DF* test was not computed for it.

2. In fact, using the Engle and Granger (1987) two step estimation method we were not able to find an error correction form which might explain the underlying data generation process.

3. Although the DF* test indicates that the W_t series is not I(0) while the C_t series is I(0), the DF and CRDW tests indicate that these series are both I(1) and also cointegrated. As the structural changes are not filtered out in our estimations, the cointegration result appears reasonable.

4. It does not make any difference whether the supply (or demand) equation is derived by imposing restrictions on the quantity rather than the price equation.

5. When the export price was included in the system and subsequently in the demand equation instead of the lagged stumpage price, the structural form did not pass the test for overidentifying restrictions and the demand equation also fitted the data poorly in the 2SLS and 3SLS estimations. Also, the long-run elasticities became unrealistically high, probably due to the small sample bias.

6. There are practical problems involved in including the energy input in the analysis. Apart from mechanical pulp mills, the pulp industry is self-sufficient in energy input and therefore it is difficult to derive a consistent price for energy input (see Hetemäki 1990).

7. According to the omitted variable test (see Hendry, 1989, p. 56), the cross effect of the sawtimber stumpage price was not significant and was therefore omitted from the final supply function (eq. (9)). Kuuluvainen et al. pointed out the problem of possible collinearity between the sawtimber and pulpwood prices, which may weaken the ability to separate the effects of different price variables (p. 199).

8. The estimation results for the reduced form equations of the Kuuluvainen et al. model showed that the reduced form of this model is also a statistically adequate representation of the sample data.

9. The results from the Granger causality test (Hendry 1989) showed that using one, two or three lags, the null hypotheses that the stumpage price does not Granger-cause stumpage quantity can be rejected at the 5 percent significance level for all three lags. On the other hand, the null hypotheses that stumpage quantity does not Granger-cause stumpage prices could be accepted for all three lag specifications. Consequently, simultaneity is not a problem in the model.

10. Note that using P_t and P_{t-1} on the right hand side of the regression equation is identical to using P_t and ΔP_t. In the latter case the coefficient of P_t gives directly the long-term effect if the lagged dependent variable is not included among the regressors.

REFERENCES

Adams, D.M. & Haynes, R.W. "The 1980 Softwood Timber Assessment Market Model: Structure, Projections, and Policy Simulations." *Forest Science monograph* no. 22, (1980).

Bhargava, A. "On the Theory of Testing for Unit Roots in Observed Time Series". *Review of Economic Studies* LIII(1986): 369-384.

Binkley, C. S. Timber Supply from Private Nonindustrial Forests. A Microeconomic Analysis of Landowner Behavior. Yale University: School of Forestry and Environmental Studies, Bulletin 92 (1981).

Brännlund, R., Johansson, P-O, & Löfgren, K.G. "An Econometric Analysis of Aggregate Sawtimber and Pulpwood Supply in Sweden." *Forest Science* 31(1985): 595-606.

Engle, R. F. and Granger, C. W. J. Co-Integration and Error Correction: Representation, Estimation, and Testing." *Econometrica* 55(1987): 251-276.

Forsman, P. & Heinonen, T. "Dynamic Models of the Roundwood Market in Finland." *Finnish Economic Papers*, vol. 2(1989): 48-54.

Fuller, W.A. *Introduction to Statistical Time Series*. John Wiley & Sons, 1976.

Hendry, D.F. "Encompassing." *National Institute Economic Review*, August (1988): 88-92.

——— *PC-GIVE, An Interactive Econometric Modelling System*. University of Oxford, 1989.

____ and Ericsson, N.R. "An Econometric Analysis of U.K. Money Demand in *Monetary Trends in the United States and the United Kingdom* by Milton Friedman and Anna J. Schwartz" *American Economic Review*, 1(1991): 8-38.

____ Neale, A.J. & Srba, F. "Econometric Analysis of Small Linear Systems Using PC-FIML." *Journal of Econometrics* 38(1988): 203-226.

Hetemäki, L. "Factor Substitution in the Finnish Pulp and Paper Industry", *Acta Forestalia Fennica*, no. 211 (1990).

_______ and Kuuluvainen, J. "Supply of and Demand for Pulpwood in Finland" in Haynes, R.W. (ed.) Proceedings of the International Union of Forest Research Organizations (IUFRO), Forest Sector Analysis Working Group Meeting in Montreal, 5.-11.81990.

_________, "Incorporating Data and Theory in Roundwood Supply and Demand Estimation", *American Journal of Agricultural Economics* (forthcoming).

Hultkranz, L and Aronsson, T. "Factors Affecting the Supply and Demand of Timber from Private Nonindustrial Lands in Sweden: An Econometric Study." *Forest Science* 35(1989): 946-961

Hylleberg, S. and Mizon, G.E. "A Note on the Distribution of the Least Squares Estimator of a Random Walk with Drift, *Economic Letters*, (1989) 29: 225-230.

Judge, G.G., Griffiths, W.E., Hill, R.C., Lutkepohl, H. & Lee, T-C. *The Theory and Practice of Econometrics*. Second edition, 1985.

Koskela, E. "Forest Taxation and Timber Supply under Price Uncertainty: Perfect Capital Markets." *Forest Science*, **35**(1989a): 137-159.

—— "Forest Taxation and Timber Supply under Price Uncertainty: Credit Rationing in Capital Markets." *Forest Science* **35**(1989b): 160-172.

Kuh, E. & Schmalense, R. *An Introduction to Applied Macroeconomics*, orth-Holland, 1973.

Kuuluvainen, J. "An Econometric Analysis of the Sawlog Market in Finland." *Journal of World Forest Resource Management* 2(1986): 1-19.

—— "Virtual Price Approach to Short-Term Timber Supply Under Credit Rationing." *Journal of Environmental Economics and Management,* 19(1990): 109-126.

____ , Hetemäki, L. Ollonqvist, P., Ovaskainen, V., Pajuoja, H., Salo, J., Seppälä, H., Tervo, M. "The Finnish Roundwood Market: An Econometric Analysis." *Finnish Economic Papers* 1(1988): 191-201.

______ and Salo, J. "Timber Supply and Life Cycle Harvest of Nonindustrial Private Forest Owners", *Forest Science*, 1991, vol.37, no.4:1011-1029.

McKillop, W. "An Econometric Model of the Market for Redwood Lumber." *Forest Science* 15(1969): 159-170.

Newman, D.H. "An Econometric Analysis of the Southern Softwood Stumpage Market: 1950-1980." *Forest Science* 33(1987): 932-945.

Perron, P. "The Great Crash, the Oil Price Shock, and the Unit Root Hypothesis", *Econometrica* 57(1989): 1361-1401.

Phillips, P.C.B. "Understanding Spurious Regression in Econometrics." *Journal of Econometrics* 33(1986): 311-32.

_____ and Durlauf, S.N. "Multiple Time Series Regression With Integrated Processes." *Review of Economic Studies* LIII(1986): 473-495.

Robinson, V.L. "An Econometric Model of Softwood Lumber and Stumpage Markets, 1947-1967." *Forest Science* 20(1974), 171-179.

Spanos, A. *Statistical Foundations of Econometric Modelling*. Cambridge University Press. Cambridge, 1986.

_______ "Simultaneous-Equations Model Revisited." *Journal of Econometrics*, (1990):87-105.

APPENDIX I. FORMULAE FOR THE TEST STATISTICS USED

A number of different test statistics are computed for the individual time series and estimated equations. These tests are briefly described below. For a more detailed description of most of the tests, see Hendry (1989).

The notation for different time periods and variables is:

T_1 = beginning of the sample period,

T_2 = end of the sample period,

$T = T_2 - T_1$ = number of observations used for estimation,

N = number of observations used for forecasts, and

k = number of variables.

When Recursive Least Squares (RLS) is used, M is the number of observations used for the initial estimates $t = T_1 + M, \ldots, T_2$.

i) The *normality test*, χ^2_N, is based on testing whether skewness (SK) and excess kurtosis (EK) are jointly zero. $\chi^2_N = (T-k)\,(SK^2 + 0.25\,(EK)^2)/6$. It may be noted that particularly in the small samples, one should also examine the graph of the density function since, for example, an outlier observation may bias the test.

ii) The *Dickey-Fuller (DF)* unit root test tests the hypothesis H_0: $\rho = 1$ (random walk) against H_1: $\rho < 1$ (stationary) in the model $y_t = \rho y_{t-1} + \varepsilon_t$, $\varepsilon_t \sim IN(0, \sigma^2)$. If we subtract y_{t-1} from both sides, we get

$$(6) \qquad \Delta y_t = \beta y_{t-1} + \varepsilon_t$$

with rejection of the hypothesis of a unit root $\rho = 1$ (i.e. $\beta = \rho - 1 = 0$) if the "t" value is sufficiently negative. Because the statistic has a nonstandard distribution under the null, critical values using Monte Carlo simulations have been computed and tabulated (see, e.g., Fuller (1976), Engle and Granger (1987) and Hylleberg and Mizon (1989).

iii) The *Durbin-Watson (DW)* unit root test tests the simple random walk model against the stationary alternative. If the series is a random walk, DW statistics will be very small. Critical values for DW test have been simulated, e.g. by Bhargava (1986).

iv) In the *modified Dickey-Fuller test (DF*)*, the null hypothesis considered is that y_t is a realization of a time series process characterized by the presence of a unit root and possibly nonzero drift (μ), deterministic time trend (T) and a dummy variable permitting a one-time change in the structure occurring at a time T_B ($1 < T_B < T$). In line with Perron (1989), three different models are considered under H_0. First, the "crash" model, which allows an exogenous change in the level of the series, second, the "changing growth" model, which permits an exogenous change in the rate of growth, and a third model that allows both changes. For a more detailed description of the test procedure in the context of present data, see Hetemäki and Kuuluvainen (1990).

v) The *Auto Regressive Conditional Heteroscedasticity* (F_{ARCH}) test tests the null hypothesis $\varphi = 0$ in the model $E(\mu_t{}^2 \mid \mu_{t-1},\ldots\mu_{t-r}) = \omega_0 + \sum_1^r \varphi\mu_{t-i}^2$.

vi) The *autocorrelation test* F_{RAC} is a test which is valid with a lagged dependent variable. The test is calculated as $\mu_t = \sum_{i=\rho}^{r} \alpha_i\mu_{t-1} + e_t$, where ρ ($0 \leq \rho \leq r$) and r are selected. The null hypothesis is that all α_is are zero, or there is no autocorrelation.

vii) The F_c *(or RESET)* test tests the null hypothesis of correct functional specification of the original model against the alternative specification in which powers of linear combinations of the right hand side variables are included.

viii) *F -test.* A test for whether all the parameters, except the constant, are significant. This is a measure for whether the regression equation is an adequate statistical representation. The formula is:

$$Z_1 = \frac{R^2/(k-1)}{(1-R^2)/(T-k)} \sim F_{(k-1,\ T-k)} \text{ on } H_0\text{: } \beta = 0$$

ix) F_F *-test.* This is a Chow test for parameter constancy for N forecasts. Rejection of the null hypothesis implies a rejection of the model used over the entire sample period. The test is calculated as:

$F = ((RSS_{T+N} - RSS_T)(T_2 - T_1 + 1 - k))/(RSS_T)N.$

x) χ^2_I *-test.* This is a specification test for the validity of the instruments used in 2SLS estimation.

xi) $\chi^2_{\alpha=0}$ -test. This is a test for 2SLS estimation and is the analogue of the OLS F -test (see, viii)), i.e. it tests whether all the parameters, except the constant, are insignificant.

xii) χ^2_F *-test.* This is an index of numerical parameter constancy for N forecasts. It is calculated as $\chi^2_{(N)/N}$.

xiii) χ^2_{OI} *-test.* This is a test for the validity of restrictions imposed on the reduced form. The null hypothesis (H_0) specifies that the variables which are postulated not to occur in the equation have zero coefficients in that equation, while the alternative hypothesis (H_1) specifies that at least one of these coefficients is not zero. Thus, H_1 states that H_0 declares too many variables to be absent from the equation. If the reduced form restrictions "over-identify" the model, the resulting model will not encompass the statistical model (system) and will not be a valid representation of the DGP. The test is asymptotically distributed as $\chi^2_{(J-K^2)}$, where J is a priori restrictions and K stochastic equations. If the statistic is significant, the over-identifying restrictions are inconsistent with sample information.

xiv) The *1 -step residual test* is calculated as $(RSS_t - RSS_{t-1})/(RSS_{t-1}/t - T_1 - k)$, where RSS is the residual sum of squares $(= \sum \mu_t^2)$, T_1 is the beginning of the sample period and k is the number of variables. The test takes each error, one at the time, and fits the current period and tries to forecast the next period. In the graphs, 5 % are expected to be above the critical value.

xv).The graph for *parameter (β) constancy* shows $\tilde{\beta}_{it} \pm 2\ S.E.(\tilde{\beta}_{it})$ for each selected i $(i = 1,\ldots k)$ over $t = T_1 + M,\ldots T_2$, where M is the number of observations used for the initial estimates and T_2 is the end of the sample period.

xvi). These *Chow tests* are break point F -tests. They are called *N -step decreasing* if the number of forecasts (N) go from $N = T_2 - T_1 - M$ to 1. They are calculated as $((RSS_{T_2}-RSS_t)(t-T_1-k))/RSS_t(T_2-t)$. They are called *N -step increasing* if the forecast horizon increases from T_1+M+1 to T_2. They test the model over T_1 to T_1+M against an alternative which allows any form of change over $t=T_1+M+1$ to T_2. They are calculated by $((RSS_t-RSS_{T_1+M})(M-k))/((RSS_{T_1+M})(t-T_1-M)$. The result of this test may vary a lot with the selected initial period (T_1+M+1).

APPENDIX II DATA AND VARIABLES

Stumpage quantity (Q_t) is the total quantity of spruce, pine and nonconiferous pulpwood from nonindustrial forests traded in felling seasons (mill cu m). Series by felling seasons are used, since, for example, roundwood purchased in the felling season 1987/88 was mainly used in industry in the calendar year 1988. *Source: Archives of the Department of Mathematics, Finnish Forest Research Institute (FFRI).*

Stumpage price (P_t) is the (quantity) weighted average of stumpage prices (FIM/cu m) for the different types of wood in cutting seasons. Stumpage prices are prices agreed upon in sales on the stump. *Source: Yearbook of forest statistics (FFRI)*

Export price (PX_t) is the price index (1949=100) of exports (fob) for the manufacture of paper and paperboard (SITC 64). *Source: ASTIKA, Central Statistical Office of Finland (CSOF)*

User cost of capital (C_t) was calculated using the formula

$$C_t = q_t(R_t + d - g_t)/p_t,$$

where C_t is user cost, r_t is average bank lending rate, q_t is implicit price index of investment, d is depreciation rate, g_t is capital gains (expected change in the prices of capital goods), and p_t is production price index. The constant rate of economic depreciation was obtained using the procedure presented in Kuh, E & Schmalense, R. *Sources:* The series for gross fixed capital formation in current prices and in 1985 prices (used to construct the implicit price index of investment) were taken from *National Accounts*, and production price index and wholesale price index from *Statistical Yearbook of Finland*, both published by the *CSOF*.

Wages (W_t) are defined as total wages plus social security charges divided by hours worked, normalized to 1985=1. *Source: National Accounts, CSOF*

Average bank lending rate (R_t). *Source: Bank of Finland, Monthly Bulletin.*

Disposable income (I_t) is aggregate household disposable income (FIM million). *Source: Bank of Finland Quarterly Model of the Finnish Economy*

Allowable drain (V). Because the total wood volume is not available on an annual basis, we use the allowable drain (growth adjusted for age structure) as a proxy for this variable. Allowable drain has been estimated on the basis of the latest results of the National Forest Inventory and it is assumed that the present level of silvicultural and forest improvement work continues and that intensive utilization of forest resources will be extended to cover all parts of the country. *Source: Yearbook of forest statistics, Finnish Forest Research Institute.*

Tämä on viimeinen numero Metsäntutkimuslaitoksen, Metsäekonomian tutkimusosaston Tiedonantoja -sarjassa. Vuonna 1992 voimaan tulevan organisaatiouudistuksen mukaan Metsäntutkimuslaitoksen Metsäekonomian tutkimusosasto muodostaa pääosin Matemaattisen osaston ja Metsänarvioimisen tutkimusosaston tutkijoiden ja henkilökunnan kanssa uuden **Metsien käytön tutkimusosaston**. Metsien käytön tutkimusosasto tulee julkaisemaan omaa Tiedonantoja -sarjaa.

This is the last issue in the Finnish Forest Research Institute, Department of Forest Economics Working Paper -series. Due to the change in the organization of the Finnish Forest Research Institute, beginning 1992, the Department of Forest Economics merges with parts of the Department of Mathematics and the Department of Forest Inventory and Yield to form the **Department of Forest Resources**, which will publish its own Working Paper -series.

Metsäekonomian tutkimusosastolla viimeksi ilmestyneet Metsäntutkimuslaitoksen Tiedonantoja -sarjan julkaisut:

307 Veli-Pekka Järveläinen ja Veli Snellman. Energiapuun hakkuiden kehitys Virtain yksityismetsissä. 58 s.1988.

309 Matti Palo & Jyrki Salmi. Deforestation or development in the third world? Volume II. 182 s. 1988.

312 Mikko Tervo ja Aila Janatuinen. Suomen havusahatavaran viennin suhdanneindikaattorit. 52 s. 1988.

313 Mikko Tervo, Jarmo Mäkelä ja Riitta Hänninen. Dynaaminen kysyntämalli Ison-Britannian maittaiselle sahatavaran tuonnille. 35 s. 1988.

317 Heikki Pajuoja (Toim.). Metsäalan rakennemuutoksen vaikutukset alan ammattiryhmiin. 85 s. 1988.

318 Heidi Vanhanen. Small firms in the periphery: a discussion on the small sawmills of North Karelia. 40 s. 1988.

331 Leena Petäjistö, Tapio Hankala & Sirpa Onttinen. Puu ja turve teollisuuden polttoaineena 1986. 40 s. 1989.

349 Matti Palo & Gerardo Mery (Toim.). Deforestation or development in the third World? Volume III. 189 s. 1990.

364 J. Ashley Selby. Finnish land use policies: from disintegration to integration? Suomalainen maankäyttöpolitiikka: hajaannuksesta yhtenäisyyteen? 43 s. 1990.

365 Mika Mustonen. Pellon metsittämiseen vaikuttavat tekijät. 62 s. 1990.

392 Pekka Ripatti. Ennakkotuloksia yksityismetsälöiden omistajavaihdoksista ja osittamisesta. 39 s. 1991.

ISBN 951-40-1187-2
ISSN 0358-4283

HAKAPAINO OY, HELSINKI 1992