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Modeling and forecasting the demand for sawnwood in western Europe from an end-use perspective

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ABSTRACT

The traditional analysis of sawnwood demand is based on the aggregate relationship between sawnwood consumption and GDP. Sawnwood is, however, used in a variety of sectors with different consumption patterns. To account for the specific characteristics of end-uses sector models are applied. Sector classification is undertaken, a data base is constructed, and econometric models are specified for the activities in these sectors and, in some applications, for the market share of sawnwood in the sector to account for substitution. This approach has been used in analysing and forecasting the demand for sawnwood in Sweden, Norway, United Kingdom and Germany. In some of the applications, Seemingly Unrelated Regressions (SUR) and Vector AutoRegression (VAR) models are used.

Keywords: Econometric models, end-use analysis, sawnwood demand, sector models, Seemingly Unrelated Regressions, substitution, Vector Autoregression.

INTRODUCTION

The demand for sawnwood is generally analysed on an aggregated level, where the most important explanatory variables in econometric models are GDP (FAO, 1985), construction (Martin et al, 1988) or an end-use indicator (FAO/ECE, 1986). Sawnwood is, however, used in a number of sectors and its consumption pattern differs substantially among sectors. One important determinant of sawnwood demand is substitution, which is difficult, if it all possible, to analyse on an aggregate level since the underlying consumption patterns vary considerably between sectors. The conclusion is that end-use (or sector) analysis is essential for understanding the behaviour of sawnwood demand; specifically because substitution requires disaggregated analysis and each sector has its own consumption pattern that should be accounted for in the analyses.

OBJECTIVES

The objective of this paper is to present the methodology of constructing the data base, sector modelling and forecasting sawnwood consumption in a given country from the standpoint of (end-use) sector classification. More precisely, the objective is

- to specify homogenous sectors with respect to sawnwood consumption
- to produce a time series data base for sawnwood consumption by sector for analysis and forecasting
- to specify a set of models that explain consumer behavior in the sectors that are based on sound theoretical formulation and practical consideration
- to use the estimated model system to produce forecasts.

The objective of this paper is to give an overview of the research in this field, an outline of modelling approaches and to present some aggregate results with examples of details.

DATA

No time series data base exists for any country regarding quantities of sawnwood consumption by sector. Cross sectional studies may exist for some years that provide us with quantitative information about sawnwood used in various sectors. Here, a methodology has been developed based on previous studies (e.g. Cardellicchio & Veltkamp, 1981) to construct a consistent time series data base for end-uses of sawnwood. Existing cross sectional end-use studies constitute one piece of information necessary for construction of approximate historical data. The other source is time series data from available construction and industry statistics for the country studied. By combining these different data sets an annual data base is set up that covers the period from, say, 1980 to the present day. One complication, however, is that for a given country, sector classifications in cross-sectional studies are often inconsistent over time.

The classification of end-use sectors depends on the availability of data and the objective of analysing homogenous sectors with respect to sawnwood demand. The sector classification in Table 1 is appropriate for the United Kingdom.

Table 1. Sector classification for the United Kingdom.**Construction**

- New dwellings
 - Private
 - Traditional
 - Timber framed
 - Non private; 'Public' and 'Housing Associations'
 - Traditional
 - Timber framed
- Non-domestic constructions
 - Education
 - Health
 - Industries
 - Commercial
 - Other non-domestic constructions
- Other construction
 - Civil engineering
 - Scaffolding
 - Portables
 - Agricultural/horticultural (which are not dwellings)
 - Mining and quarrying
- Repair, Maintenance and Improvement (RMI)

Joinery

- Windows
- Doors
- Floors
- Stairs and ladders
- Fencing

Furniture**Packaging incl pallets****Do-It-Yourself (DIY)****Other uses**

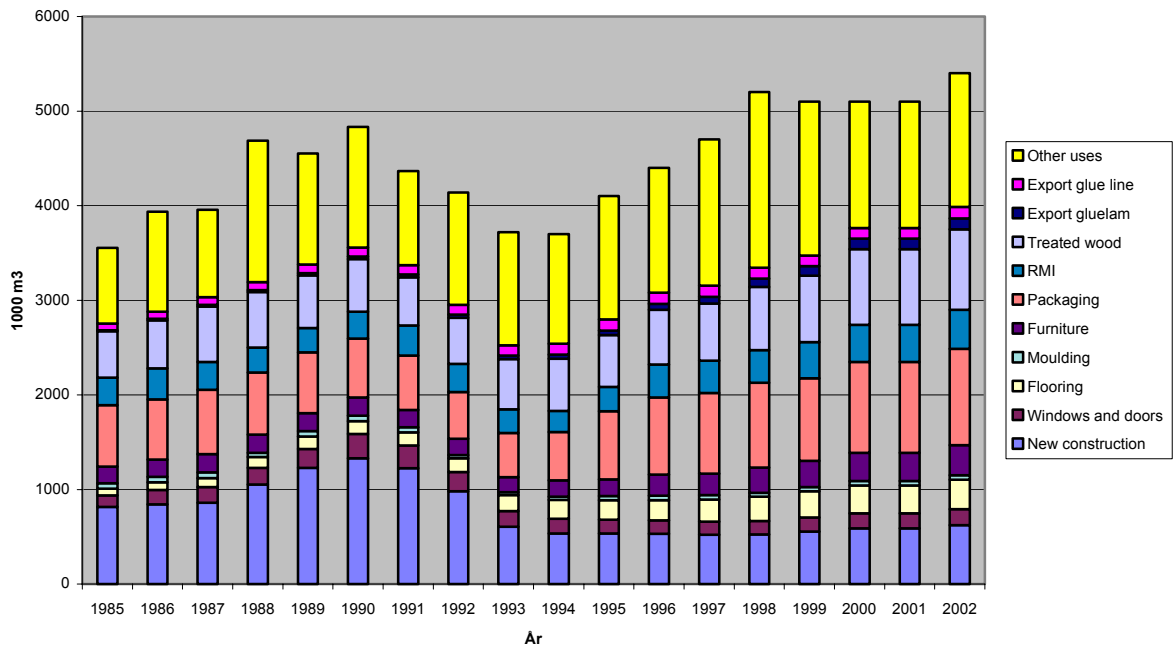
Here, joinery is not included in construction to avoid double-counting. Joinery is partly used in RMI, but is here included under joinery. 'Other uses' include mouldings, glue-laminated wood, coffins, specially treated wood, instruments etc. The sector classification varies among countries because of different consumption patterns and differences in available data.

The data used in the construction of the database are essentially based on building, construction, other industrial statistics (production, imports and exports) and national accounts data. Price and cost data are obtained from Central Statistical agencies as well as from sector organizations.

Key numbers are essential for constructing the time series of sawnwood used in the sectors. For new housing, time series of the number of housing starts exist in official publications. Cross

sectional studies may give the amount of sawnwood used per dwelling. Multiplication of the key number by the number of housing starts give approximate quantities of sawnwood used for new housing. Similar calculations are undertaken for other sectors where the key numbers may be the amount of wood used per invested GBP, for instance. All information of variation over time for key numbers exist, it is used in constructing the time series database.

The estimated consumption of soft sawnwood in Sweden is given in Figure 1 for the period 1985 to 2002 with the corresponding classification in Sweden. Here the total is the officially reported level of sawnwood consumption.



A pilot study was carried out for Norway (Baudin & Solberg, 1986, 1987 and 1989) with only five end-use sectors analysed. In the Swedish study (Baudin, 1989A, 1989B and 1990, Lönner 1991) 14 sectors were analysed and forecast, and in the UK study (Baudin, 1992, 1993) 19 sectors were analysed and forecast. In a study for Germany, 21 sectors were investigated (Flinkman, 1993, 1994). An update for Sweden was done by Dackling (2001).

The time series obtained are short both for modeling and proper long term forecasting purposes. This, however, is the only data set available at this detailed level.

The second step of the forecasting procedure involves the specification and estimation of econometric demand models. The third step entails forecasting of demand by using input forecasts on exogenous variables (GDP; private consumption, interest rates, inflation ect) from national sources, such as NEDO in the UK, the IFO-institute in Germany and the Swedish Government's Long-Term Studies.

MODEL FORMULATION

The demand for sawnwood and its substitutes is basically a function of the variation and level of activity in the different economic sectors which use forest products. It is also a function of the intensity of their utilization for different end uses. The level of consumption of sawnwood is therefore affected both by changes in the level of activity of the end use sectors and by changes in the patterns of use (substitution).

Models of this type are intended to cover two alternative aspects of sector demand: demand for wood products in the sector in terms of units produced, production value etc. or demand for the sector's output, where wood is one of many competing products.

Priority is given to primary data in the analysis; estimated quantities of sawnwood used in sectors are not included in the econometric models. In forecasting sawnwood consumption for dwellings, for instance, the number of dwellings produced is the target variable. Only at the final step of the forecasting procedure are key numbers such as the assumed average use of sawnwood per dwelling etc. used to make final calculations of quantities of sawnwood used in the sectors.

The econometric models can be classified as combined factor/consumer demand models, derived from the following considerations.

(i) Total production in sector m can be represented by a twice differentiable production function

$$y_{mt} = y_{mt}(v_{mt}, z_{mt}, t) \quad (1)$$

where y_{mt} is the production output from sector m during time period t

v_{mt} is the input of sawnwood in sector m during time period t

z_{mt} is a vector of other production inputs in sector m during time period t

t is a time index representing technological change; $t = 1, \dots, T$.

Minimizing costs subject to (1) and with prices given, Shepard's lemma implies that producers' demand for sawnwood in sector m during time period t will be

$$v_{mt} = v_{mt}(p_{0t}, p_{1t}, \dots, p_{nt}, t) \quad (2)$$

where p_{0t} denotes the unit price of sawnwood during time period t ; $p_{1t}, p_{2t}, \dots, p_{kt}$ are unit prices of other inputs in sector m ; and $p_{k+1,t}, \dots, p_{nt}$ are unit prices of all other goods during time period t .

Now, y_{mt} is determined by consumer demand. If the utility function is maximized for individual i subject to income constraint I_{it} we obtain

$$y_{mit} = y_{mit}(p_{0t}, p_{1t}, \dots, p_{nt}, I_{it}) \quad (3)$$

where y_{mit} is the i th individual's demand for product m during time period t .

On the assumption that identical and homotetic utility functions exist (i.e. income changes do not alter proportions) an aggregation across individuals gives

$$y_{mt} = y_{mt}(p_{0t}, p_{1t}, \dots, p_{nt}, Y_t) \quad (4)$$

where Y_t is the average per capita income during time period t .

According to information theory, it is reasonable to assume that time is needed for consumers (whether they are 'individuals' or 'organizations') to react to changes in income or prices. Thus time t is included in the model as an explanatory variable, giving

$$y_{mt} = y_{mt}(p_{0t}, p_{1t}, \dots, p_{nt}, Y_t, t) \quad (5)$$

Alternatively, and using the same argument, lagged variables can be included in the model. The dependent variable can be lagged as can independent variables.

Now, combining (2) and (4), we obtain

$$v_{mt} = h_m(p_{0t}, p_{1t}, \dots, p_{nt}, Y_t, t) \quad (6)$$

The data quality does not permit v_{mt} to be used directly in the analysis, since only estimated quantities of sawnwood are available. Instead, primary data are used: the number of dwellings, the number of windows, the value of wooden packaging etc. When primary data are available, key numbers are applied to them, e.g. the sawnwood content per dwelling, per window, per GBP of sales of wooden packaging, to give us sawnwood consumption forecasts.

The estimated sector models are log-linear, where coefficients are directly interpreted as elasticities.

A log-linear model for a given sector is specified as

$$\ln y_t = \alpha + \beta_1 \ln x_{1t} + \beta_2 \ln x_{2t} + \dots + \beta_p \ln x_{pt} + u_t \quad (7)$$

where $\ln y_t$ denotes the natural logarithm for the dependent (endogenous) variable time period t

$\ln x_{1t}, \dots, \ln x_{pt}$ are logarithms of independent (exogenous) variables in (6) time period t

$\alpha, \beta_1, \dots, \beta_p$ are coefficients to be estimated and

u_t is a random error with zero expectation and constant variance.

Lagged endogenous and exogenous variables can also be included in (7).

If residual analysis reveals that the model is not in equilibrium, differencing is used to achieve stationarity (Banerjee et al. 1993). For the United Kingdom, equation (7) is estimated for 11 sectors (Table 2).

Table 2. Sectors analysed by applying econometric models in the United Kingdom.

Dwellings	Other Building & Construction	Windows	Flooring
Furniture	Non-domestic constructions	RMI	Doors
Stairs	Fencing	Packaging	

The sector models seem to be unrelated, but there are common underlying structures, e.g. construction, the general trend and the business cycle. Consequently, Seemingly Unrelated Regression (SUR) procedures are applied (Zellner, 1962) since the overall precision of the models is expected to be improved if SUR-estimation is applied.

In the Swedish study, substitution analyses are carried out and particular issues of investigation considered in the Swedish analyses (Baudin, 1990) are the reasons for substitution:

- (i) Is the substitution between different materials based on price competition ?
- (ii) Is it a cost based substitution ?
- (iii) Is substitution balanced by income factors ?
- (iv) Does substitution depend on other factors such as fashion, legislation, technology which are not included in cost or price variables ?

Substitution is considered from the viewpoint of competition between sawnwood and alternative materials such as metals, fibreboard, particleboard, plastic materials, etc. The market share of sawnwood is defined as value share, volume share or surface share depending on the character of data available. For sectors where data on substitutes for sawnwood are available, the market share for sawnwood, denoted g_m in sector m , is analysed to find the causes of substitution.

The most important explanatory factors of the behaviour of the market share g_m are expected to be the real price of sawnwood (p_{0t}) and a vector of prices of substitutes (p^*_t). Other important explanatory factors are real private consumption (pc_t) and unit labour costs (c_t). The reason for including private consumption is that, with varying income, household preferences may change to other materials. Unit labour costs, c_t , are included to take application costs into consideration: Materials associated with lower application costs may be favoured at the expense of materials with higher application costs. Furthermore, a time trend variable (t) is introduced to represent other factors such as technology, fashion and legislation. Time lags of dependent and independent variables are introduced to 'explain' the inertia of the model system.

The market share model is then:

$$g_{mt} = g_{mt}(p_t, p^*_t, t, pc_t, c_t, u_t) \quad (8)$$

Here, u_t is a random error with zero expectation and constant variance. Since the market share, g_{mt} , lies in the range (0,1) the functional specification of (8) should be chosen to meet this requirement. One such specification is the logistic function, which is s-shaped ranging from 0 to 1.

Defining X_t as the vector of independent variables, p_t, p^*_t, t, pc_t, c_t , the specification of (8) is

$$g_{mt} = \frac{1}{1 + \exp(-(\alpha + \beta X_t + u_t))} \quad (9)$$

This nonlinear expression can be transformed to a linear function, a logit model:

$$\log it_{mt} = \alpha + \beta X_t + u_t \quad (10)$$

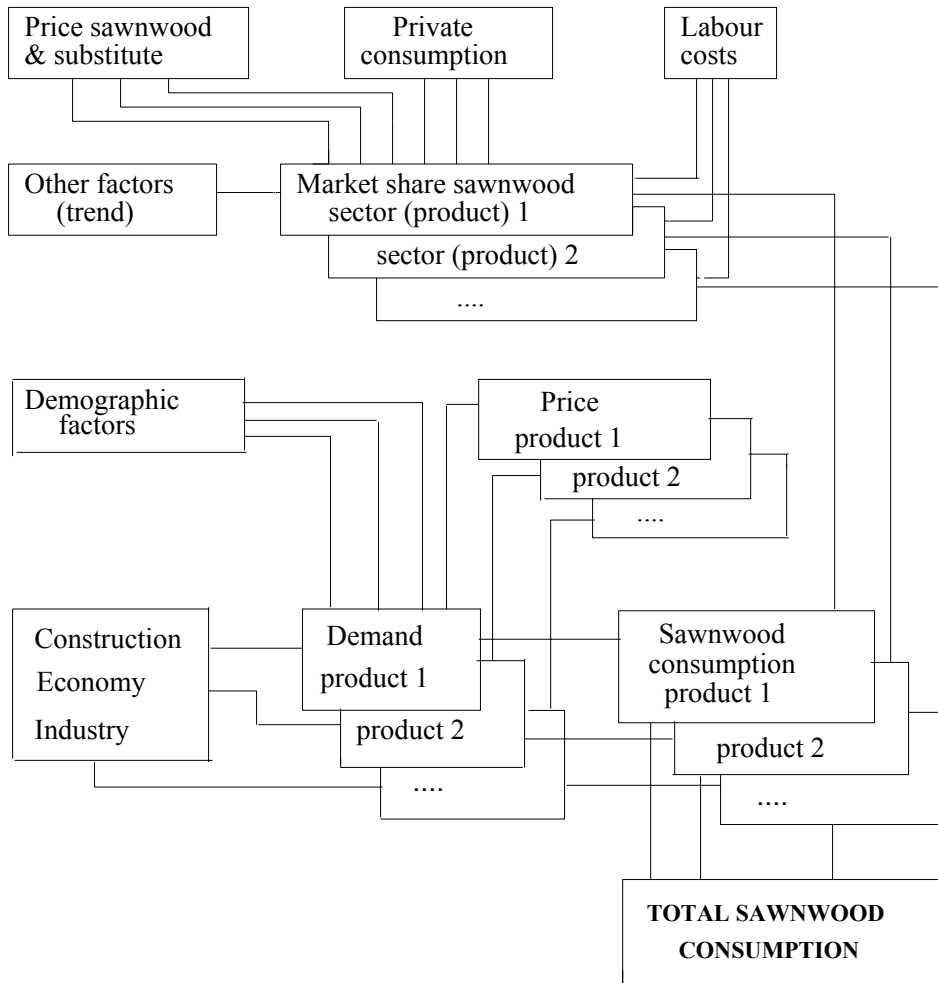
Here, $\log it_{mt}$ is the logit transform $\ln(g_{mt} / (1 - g_{mt}))$. In some model specifications the lagged dependent variable $\log it_{m,t-1}$ is included as an explanatory variable in (10) as are lagged independent variables.

With respect to the limited number of observations available and the obvious risk of multicollinearity, all variables in (7) and (10) cannot be estimated simultaneously. Therefore, a step by step procedure is applied where subsets of variables are tested and at the final stage a combination of important variables from the subsets has been retained. The procedures are manual and the choice of model is governed more by economic considerations than by significance criteria.

Substitution analysis is not carried out for the United Kingdom and Germany. Preliminary analyses for these countries revealed that the market share for sawnwood is rather constant over the observation period and, furthermore, since data for wooden materials (wooden doors, wooden windows etc.) exist, substitution analysis is not necessary. This means that, for these countries, model (7) is applied directly to the sectors, and that, e.g., the number of wooden windows, value of sales of wood furniture etc. are analysed based on the log-linear approach.

For Sweden, the model outline is presented in Figure 2 where the upper part includes the substitution (logit) models and the lower part the sector models.

Figure 2. A model of the demand for sawnwood in Sweden.



MODEL ESTIMATION

Examples of models are shown here rather than complete sets. From the set of 11 equations estimated by SUR for the United Kingdom, the equations for dwellings and windows are shown in Tables 3 and 4.

Table 3. Estimated model for housing starts in the United Kingdom.

Dependent variable: $\ln HS$, the natural logarithm of housing starts $R^2_{adj} = .68$
 Time period analysed: 1970 - 90 (annual data) $s_e = .15$
 $DW = 1.45$

Variable	Elasticity	t-value
$\ln R$	-.3505	-3.09
$\ln I$.6822	2.88
t	-.0474	-7.54

Independent variables:

$\ln R$, the natural logarithm of the (nominal) interest rate

$\ln I$, the natural logarithm of real gross fixed capital formation

t, a time index; t=1 for 1970, t=2 for 1971 etc.

Different specifications have been tested, including the price index of new housing, the real interest rate, inflation, private consumption etc. The nominal interest rate is included in the model since it can be expected to reflect the buyers' long-term cost expectations. Gross fixed capital formation is included since it can be expected that the incentives for the consumers investments in new housing are the same as the reasons for their investments in industry and the public sector. The trend is negative, indicating a decline in new housing when all other factors are kept constant. This can be an effect of long-term demographic factors such as the decline in the number of households and/or the decreasing share of young people in society.

Table 4. The estimated model for the demand for wooden windows in the United Kingdom.

Dependent variable: $\ln WIN$, the natural logarithm of the number of wooden windows produced in the UK $R^2_{adj} = .83$
 $s_e = .06$
 $DW = 1.88$

Variable	Elasticity	t-value
$\ln HS$.4571	8.47
$\ln RMI$.8723	9.98
DUM73	.3022	9.26

Independent variables:

lnHS, the natural logarithm of housing starts,

ln RMI, the log of real investment in repair, maintenance and improvement of construction

DUM73, a dummy variable, unity for 1973 and zero elsewhere.

Among the explanatory variables in this model are variables that are endogenous in other models (cf. the model for housing starts in Table 3). Here, the obvious reason is that windows are included in new buildings and repair and maintenance (RMI). The coefficients are positive: increased building activity implies increased demand for wooden windows. The elasticities are, however, less than one which can be an indication of substitution. A dummy variable is included for the extreme year 1973.

Model (10) is applied for substitution analyses. In the estimation, special attention is paid to the multicollinearity problem. Here, only one example will be shown: the market share model of packaging in Sweden (Table 5).

Table 5. A model of the market share of wood in packaging in Sweden.

Dependent variable: Logit of the (value) market share for wood in packaging

Time period analysed: 1970 - 1986 (annual data). $R^2_{adj} = .83$

$s_e = .09$

DW = 1.74

Variable	Coefficient	t-value
Intercept	-2.6254	
t	-.032325	-7.1
p_t	-.004616	-2.6
p_{1t-1}	-.013136	-2.6
p_{2t-1}	.021952	2.3

Here, p_t denotes the real unit price of sawnwood; p_{1t} is the real producer price index of paper and paperboard; and p_{2t} is the real price index of chemical products (an indicator for the price of plastic films).

The price coefficient of sawnwood is negative, which is expected from theory, while the coefficient of prices of chemical products is positive, indicating substitution between the products. The coefficient of paper and paperboard is negative which indicates that the two materials do not compete in the same segment. The trend factor is negative which means that, with all other factors constant, sawnwood will lose market share.

To obtain a figure for the level of sawnwood consumption for packaging, the market share model is supplemented by a model of the demand for packaging. The results for Sweden are shown in Table 6.

Table 6. A model for the total consumption of packaging in Sweden.

Dependent variable: The natural logarithm of the total sales of packaging in Sweden (million SEK).

Time period: 1970 - 86.

$R^2_{adj} = .76$

$s_e = .04$

DW = 2.20

Variable	Elasticity	t-value
$\ln MX_t$.754514	2.6
t	.043431	5.6
$\ln C_t$	1.374601	6.4

The index of industrial production in the manufacturing industry (MX) is an important explanatory variable, as expected. The trend factor is also important - this is positive indicating overall growth in the packaging industry. More surprising is the cost factor which has a positive sign. This could be an expression of indirect factors indicating that increased consumption of packaging materials follows from higher wages. The model fit is shown in Figure 6.

FORECASTING

To obtain forecasts of the endogenous variables of the model system the exogenous variables of the system must be forecast. The forecasting procedure is based on the following conditions:

- (i) Official macroeconomic forecasts of GDP, Private consumption, Gross fixed capital formation etc. are used as exogenous inputs to the estimated model system
- (ii) For those variables where official forecasts are not available, ARIMA-modelling (Box & Jenkins, 1976) is used to establish projections. This is the case for variables such as price levels, inflation, interest rates etc. Low and high forecasts are compared

to

average projections, where the low/high values are given by 75% confidence limits of the ARIMA - projections. Alternatively, multivariate methods such as Vector ARIMA (VARIMA) or Vector Autoregression (VAR, e.g. Lütkepohl, 1993) are applied.

- (iii) For the UK and Germany, the econometric system is estimated using SUR. Forecasts of exogenous variables are, for Germany, obtained by VAR models (Flinkman 1994).

The observations to 1988 and forecasts to year 2000 of the end-uses and total sawnwood consumption in Sweden for the main alternative forecast are presented in Table 7. We can now compare with the outcome that indicates an underestimation of the total consumption.

Table 7. The consumption of sawnwood in Sweden classified by end-use. Observations are up to and including 1988 and forecast are up to and including year 2000. Main forecast alternative. Note: Joinery includes windows, doors, flooring, moulding and interior fittings (thousand cubic meters). RMI is Repair, Maintenance and Improvement.

Year	Cons- truction	Joinery	Furni- ture	Pack- aging	Trea- ted wood	RMI	Other uses	Total
1970	1773	435	289	1351	294	81	716	4938
1975	1853	484	331	947	455	111	863	5045
1980	1298	453	240	983	461	140	1121	4696
1985	795	409	214	900	490	290	455	3553
1988	1148	516	230	1086	550	270	900	4700
1990	923	559	232	958	575	296	691	4234
1995	772	497	215	935	722	322	644	4107
2000	721	463	203	813	854	357	590	4001

In the FAO-forecast of 1985, the consumption level in the year 2000 was expected to be around 5.6 million cubic metres. This can be compared to the forecasts of FAO/ECE, the high and low alternatives of which are 5.0 million and 4.5 million cubic meters, respectively. The FAO/ECE came close to the outcome. It should, however be mentioned that the time series of sawnwood consumption was revised at the end of the decade and a measurement error of approximately one million cubic meters was discovered.

The main advantage of the end-use approach is that substitution is accounted for and consequently the forecasts are less optimistic, and so far more realistic, than in the aggregate approaches.

Alternative forecasts of the demand for sawnwood in the sectors can be derived with the objective of demonstrating forecast uncertainty. By adding the low and high alternatives, respectively, an aggregate picture of the inherent uncertainty of the forecasts can be established.

DISCUSSION

This paper presents an overview of methods used for obtaining a deeper understanding of the inherent patterns of use of sawnwood in some countries in West Europe. In situations where end-use data are not available, which is most frequently the case, the methods used here may serve as guidelines for similar studies in other countries having the same purpose. Furthermore, the methods used reveal that it is possible to specify and estimate sector demand models. It is then possible not only to study total demand in a sector but also to find reasons for substitution. Generally it has been found that macro-economic factors such as GDP play a less dominant role in end-use analysis than in aggregate analyses. Instead, factors such as investment, interest rates, industrial production and prices of final products are important determinants of sector growth in sector models. Substitution, in positive or negative directions, occurs as a consequence of price

changes for sawnwood relative to competing products. One consequence is that the forecasts obtained from end-use analysis differ substantially from those obtained from more aggregate analyses. In general, the end-use (disaggregate) analyses give lower projections than those obtained from aggregate analyses.

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