FORECASTING DANISH TIMBER PRICES WITH AN ERROR CORRECTION MODEL

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ABSTRACT

Annual Danish timber prices 1954 through 1992 are modelled along with a corresponding Swedish price series in a vector autoregressive (VAR) system. The two sets of prices are found to be cointegrated which indicates economic integration of the two markets. Restrictions on the cointegration relationship are imposed to test for weak exogeneity of the Swedish price with respect to the long-run parameters. Departures from the estimated long-run equilibrium with the Swedish price are modelled by percentage changes in Gross National Product (GNP) and an index for the building activity (BA). The resulting model is used for forecasting the Danish timber price.

Keywords: Cointegration, forecasting, timber prices, weak exogeneity.

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INTRODUCTION

Optimization of the timber rotation period when prices are stochastic has for decades constituted a challenge for forest economists. In the case of stationary prices a trading rule based on a benchmark price is often used to adapt behaviour to variations in timber prices — see *inter alia* Lohmander (1987), Brazee & Mendelsohn (1988), Haight (1991) and Teeter & Caulfield (1991). Similar analyses have been performed in the case of nonstationary prices (Haight & Holmes, 1991; Thomson, 1992). Common for all approaches is that only the information contained in the previous prices is utilized. In this paper the price is forecasted using additional information.

The forecasting model applied here is a vector autoregressive model (VAR) in error correction form (ECM). This modelling strategy was introduced and popularized by Davidson et al. (1978) in a paper on the relationship between consumption and income in the U.K. The ECM has been widely applied in various fields of economics and in natural resource markets it has been applied

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for testing land valuation models (Hallam *et al*., 1992; Lloyd, 1994), dynamics of livestock prices (Kesavan *et al*., 1992), supply response (Hallam & Zanoli, 1993) and, similar to this paper, for analysis of the integration of spatially linked markets (Alexander & Wyeth, 1994; Bessler & Fuller, 1993). Finally, Sarker (1993) has analysed the cointegration relationships between Canadian lumber exports and U.S. lumber prices, housing starts and the exchange rate.

In this paper the process of deriving at a forecasting model for the domestic timber price involves an analysis of the integration of the Danish market with the surrounding markets. The statistical framework imply a possibility to test hypotheses about the structural relations. This is done by imposing restrictions on the long-run coefficients in the model. Thus, the forecasting model applied has an additional potential, besides assisting in forecasting; it has an interpretation usable for gaining insight in the dynamics of the economic system.

The next section provides some features of the Danish timber market that influence the choice of explanatory variables in the forecasting model. The third section gives a verbal presentation of the basic trade model underlying this study. The fourth and fifth sections provide tests of the order of integration of the variables and results of the VAR analysis, respectively. Following are the forecasting results and a final section that concludes the paper.

The Danish Timber Market

Eighty percent of the forest industries' coniferous roundwood consumption is supplied from domestic sources (Ministry of Agriculture, 1994). Of the 20 percent imported some is high quality timber that does not immediately substitute for domestically grown timber. Thus, domestic supply comprises the main source of raw material for the forest industries.

Primary domestic production (total net increment) forms the basis for supply. It is, due to the nature of forestry, a fairly smooth function over time. Secondary production — harvesting — is not linked to the biological process in the short run and is potentially much more volatile. Supply could, apparently, play an important role in formation of the domestic timber price. Nevertheless, it is chosen in this study to focus on the demand side and the influence on price from the international price development. The following list justify the exclusion of the supply side (annual domestic harvest) from the model. The reasons for a weak response to price development when looking at the aggregate sector (using data from 1954 through 1992) are:

1. Forest managers faced labor capacity constraints limiting the ability to respond to changes in demand.
2. Silvicultural constraints. The intensively managed coniferous stands have limited degrees of freedom regarding postponement of thinnings. Biological instability of mature stands in some cases makes little room — if any — for timing of the clearcutting.
3. Financial stress of private estates often forces managers to perform extensive cuttings when prices are low in order to provide a fixed annual revenue to meet financial requirements.
4. A progressive tax system makes it less attractive to vary income from forestry over the years.
5. Joint operations (e.g., agriculture and forestry) or vertical integration (e.g., forestry and sawmill) introduces aggregate measures of performance. This puts less weight on harvest optimization.
6. Lack of forecasts. When prices are considered by the individual manager to resemble a random walk the optimal strategy is to cut stands when they reach the Faustmann optimal rotation age (Proof by contradiction: Managers cannot choose between a shorter and a longer rotation period when $E(\Delta p_{t+1}|I_t)=0$, where I_t is the information on previous price development).

In one case the quantity released has had extensive effect on the price. In 1967 an extensive windthrow caused a market breakdown and drastically falling prices. This incident is modelled using a dummy variable. The reasons for price fluctuations additional to those induced by changes in the Swedish market should thus be sought on the demand side.

A review of annual market reports (Riis, 1996) supports the perception of the market as being driven by changes in demand and the international developments. In the period 1954 through 1992 the primary influences repeatedly mentioned in the reports are:

(i) building activity,

(ii) fishing activity[1],

(iii) export possibilities/import pressure,

(iv) general economic recession/prosperity and

(v) windthrows.

Of the reasons mentioned, all but windthrow influence demand and all can be assumed exogenous to the timber market.

The aim here is to find determinants of demand for timber. With the variety of end-uses for timber it is difficult to single out variables that will describe the price development. The primary end-use for timber is sawn timber for construction. A proxy for demand for timber for construction is housing starts or other measures of building activity (such as: completed floorage, commenced floorage, or persons employed in the construction sector). In this study an index for the building activity based on annual commenced floorage is used. However, the index has some draw-backs when used over the entire period. The fraction of timber used for construction has decreased since the 1950s when the housing market was heavily underdeveloped due to recession in the 1930s and stagnation during World War II. In the last part of the period the demand for new housing was close to saturated with more emphasis on renovation of existing houses. Furthermore, the amount of sawn timber used per square meter has decreased through the period due to competition from steel and concrete. Also the shift from private houses to office buildings with constructions heavily depending on concrete elements weakens the explanatory power of the index.

[1] Timber substitutes qualities primarily used for production of packing materials. Fishing activity is not an important factor in the last part of the period since plastic has replaced wood as the primary material for making fish boxes.

To capture the demand for wood for all the other increasingly important purposes a possibility is to move up one level of aggregation and look at proxies for increased activity in all areas of timber consumption. One such variable is growth in real gross national product as a measure of economic activity.

The conclusion is that a proxy for building activity (*BA*) and growth in real gross national product (*GNP%*) are appropriate variables to indicate the demand for timber.

AN ANALYTICAL FRAMEWORK

The hypothesis investigated is that a long-run equilibrium exists between the Danish domestic price and the price on the neighboring large-scale exporting market Sweden. The *Law of One Price* (Walraz, 1873) says that free trade in a reasonably homogenous product like timber should keep the price on the domestic market close to the price in the surrounding countries if transaction costs are negligable. Danish imports from the neighboring countries maintain the equilibrium by being an alternative to domestic timber. These imports are, however, subject to entering barriers such as finding new suppliers, increased paperwork connected with international trade, and use of a slightly different raw material in the manufacturing process. These barriers prevent frictionless adjustment. Long-term contracts on supply of specific quantities also have the effect of retaining the market out of equilibrium since they prevent industries from changing from domestic supply to imports and thereby putting a pressure on the price. In the long run, however, the Danish price on Norway spruce timber[2] should follow the international prices — here represented by a Swedish timber price series.[3] The actual transactions balancing prices are not necessarily timber in the form of roundwood but can be also be sawn timber, thereby assuming close to identical processing technology.

[2] Nominal price on unsorted Norway spruce timber in Denmark measured in DKK/m^3. For details on the price data see Riis *et al.* (1995).

[3] Unsorted 20 cm spruce timber from Kopparberg län. Prices are nominal delivery prices in SEK/m^3. Source: Statistical Yearbook of Forestry, Jönköping, pp. 316.

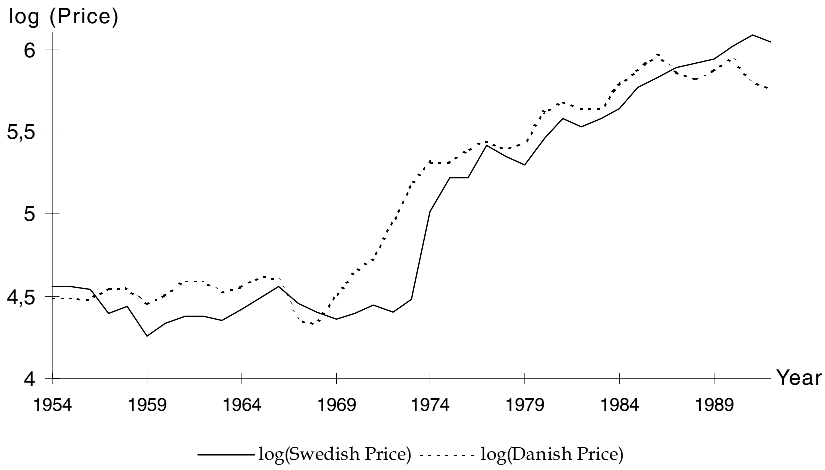

FIGURE 1. TIMBER PRICES 1954 THROUGH 1992 IN LOGARITHMS

The approach used to test the hypothesis does not require this equilibrium to be satisfied at all times. The long-run equilibrium is incorporated in the model in a way that the price development in Denmark is affected by the deviation from this equilibrium.

From Figure 1 it can be seen that the two price series follow the same general pattern although the paths differ somewhat. The fact that the Danish market is small and geographically close to a large net-exporting country like Sweden suggest that the price in Denmark is influenced by the price development in Sweden and the influence is expected to be unidirectional.

The analytic procedure is first to test the variables univariately for order of integration, i.e. to test the hypothesis of unit roots in the processes. The unit root tests influence the choice of statistical model — ignoring the issue of stationarity can invalidate the statistical inference. Then the Danish and Swedish timber price series are tested for cointegration in a bivariate model (Johansen, 1988; Johansen & Juselius, 1990). The same model is used to test for weak exogeneity of the Swedish price expressed as linear restrictions on the long-run coefficients. The resulting ECM is then used to forecast the Danish timber price and the results are evaluated.

Unit Root Tests

Even though all statistic inference regarding presence of unit roots can be obtained from the vector autoregressive (VAR) model, the individual price series are analysed univariately. The analyses serve to support the conclusions from the multivariate model and is a logic first step when modelling price series.

As an introduction to the tests of unit roots in the processes the concept of non-stationary variables is briefly outlined. The simplest example of a non-stationary times series is the random walk:

$$y_t = \beta y_{t-1} + \varepsilon_t \tag{1}$$

where $\beta = 1$ and ε_t is i.i.d. $N(0,\sigma^2)$. For this process neither the mean nor the variance is properly defined and subsequently, standard t-test statistics are not valid for values of β close to one.

One way of avoiding the problem is to make the series stationary by expressing it in differences. Subtracting y_{t-1} from both sides in (1) gives:

$$\Delta y_t = \varepsilon_t \tag{2}$$

The series is now stationary but has lost the information in the levels through the transformation. A series that can be made stationary by taking differences is said to be $I(1)$ — integrated of order one.

The univariate testing procedure for unit roots uses results from the regression:

$$\Delta y_t = \alpha + \delta t + (\beta - 1) y_{t-1} + \sum_{i=1}^{k} \varphi_i \Delta y_{t-i} + \varepsilon_t \tag{3}$$

where the parameter $(\beta - 1)$ is obtained from subtracting y_{t-1} from both sides in (1). This coefficient $(\beta - 1)$ is then testet for significance of negativity (positive deviations indicate an explosive series which often has no reasonable economic interpretation — except for hyperinflation).

TABLE 1. UNIVARIATE UNIT ROOT TESTS.

The Table reports Augmented Dickey-Fuller Test (ADF) and Phillips-Perron Tests (PP).

VARIABLE	ADF				PP
	T-STATISTIC[III]	K	TREND	CONSTANT	T-STATISTIC
P_{DK}	1.14	1	no	no	1.45
P_{DK}	-2.34^{*}	2	no	yes	-3.33^{**}
P_{SW}	−2.33	0	yes	yes	−3.28
P_{SW}	-4.61^{**}	0	no	no	-7.73^{**}
BA[I]	−1.90	0	no	yes	−1.97
BA	-5.45^{**}	0	no	no	-4.32^{**}
$GNP\%$[II]	-5.23^{**}	0	yes	yes	-5.73^{**}

[I] Building activity - an index for housing starts based on quarterly started square meters of floorage. Source: Statistics Denmark.

[II] Percentage increase in gross national product. Source: Statistics Denmark.

[III] * and ** denote significant t-statistics at the 5 and 1% level, respectively.

The lagged dependent variables are included to eliminate possible autocorrelation in the residuals. This parametric correction underlies the Augmented Dickey-Fuller (ADF) test. The Phillips-Perron (PP) test (Phillips, 1987; Phillips & Perron, 1988) uses the same regression but with $k = 0$ and the trend term defined as $\delta(t - T/2)$. The PP test is based on a correction of the t-test statistic on $(\beta - 1) = 0$ using the information in the residuals. In the PP tests reported in Table 1 up to the fifth autocovariance are used for correction of the t-statistic.

THE STATISTICAL MODEL

The alternative to differencing difference stationary variables, and thereby retain stationarity, is to linearly combine two or more such integrated series. If such series are cointegrated there exists a linear combination of the variables that is stationary. In general: The components of vector X_t are said to be cointegrated of order d, b, denoted $CI(d - b)$ if:

(i) all components of X_t are $I(d)$ and

(ii) a vector $\beta(\neq 0)$ exists so that $Z_t = \beta_t' X_t \sim I(d - b)$, $b > 0$.

The vector β is called the cointegrating vector (Engle & Granger, 1987).

Having two cointegrated $I(1)$ variables $x_{1,t}$ and $x_{2,t}$, a simple error correction model involving the first of these two variables can be written:

$$\Delta x_{1,t} = \delta \Delta x_{2,t-1} + \varphi \Delta x_{1,t-1} - \alpha\left(x_{1,t-1} - \beta x_{2,t-1}\right) + \nu_{1,t} \qquad (4)$$

This model has an i.i.d. disturbance term ν, if properly specified and then the model can be estimated consistently by ordinary least squares. It offers a means of reincorporating levels alongside differences, thus having the long-run relationship $x_{1,t} = \beta x_{2,t} + \varepsilon_t$ included in (4).

With X_t being a vector comprising the two timber prices P_{DK} and P_{SW} under investigation, (4) can be written in vector notation with additional explanatory variables and dummy variables Z_t:

$$\Delta X_t = \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \Pi X_{t-1} + \Phi Z_t + \mu + \varepsilon_t \qquad (5)$$

The model (4) is now expanded to a system of equations. The matrix of long-run multipliers Π can be decomposed into a matrix of loading factors, α, and a matrix, β, of cointegrating vectors ($\Pi = \alpha\beta'$). While α defines the weights — which can be interpreted as the "speed" with which adjustment to the steady-state relations takes place — the columns of β define the stationary linear combinations of the variables in Y_t. A rank of r means there are r cointegrating relations between vectors in Y_t. When all p vectors of Y_t are stationary, the matrix Π has full rank, i.e. rank(Π) = p. When the variables are not cointegrated and $I(1)$, the matrix Π has zero rank and (6) corresponds to a differenced vector time series model. The number of cointegrating vectors, i.e. the cointegration rank, is determined using Johansen's maximum likelihood method (Johansen, 1988; Johansen & Juselius, 1990). Testing the statistical hypothesis of cointegration is, following Ravallion (1986), a test of economic market integration. Besides testing for market integration the statistical framework can also be used to determine the issue of weak exogeneity. The statistic concept of weak exogeneity is used to test for presence of exogeneity in economic terms.

The test for weak exogeneity with respect to the long-run parameters is explained in Johansen & Juselius (1990, 1992). It is done by restricting the α-vector to be $\alpha = A\theta$, where θ is the vector of estimated coefficients and $A' = (1, 0)$. The test statistic is χ^2-distributed and results from a likelihood ratio test.

Results and Forecasts

To find the solution to the question of whether the Danish and the Swedish markets are integrated a test for cointegration of the two prices is made. It is made as a test for the rank of Π in the VAR model in (5) giving the following results reported in Table 2.

The hypothesis of no cointegration can be rejected at 1% level and thus there is one set of cointegrating vectors. The rank of Π, and thus the number of cointegrating vectors, are easily determined in this case since the hypothesis of no cointegration ($r = 0$) can be rejected and full rank ($r = 2$) would imply that all components of X_t in (5) are stationary. This is shown not to be the case in the univariate tests and confirmed by this test result.

The result of the likelihood ratio test for weak exogeneity estimated with rank $r = 1$ is a value $\chi^2(1) = 21.663$ [0.000]. The hypothesis of the Swedish price being weakly exogenous with respect to the long-run parameters is quite clearly rejected. This result is surprising, given the fact that the Swedish market is a large net-exporting market and the Danish is a small net-importing market. The consequence is that both prices need to be modelled.

Table 2. Cointegration Test Statistics for the Reduced Form VAR Model.

H_0: rank = r	λ_{max}	λ_{max}^{I}	95%	Trace	Trace^{I}	95%
$r = 0$	22.2**	19.93**	14.1	22.55**	20.24**	15.4
$r \leq 1$	0.35	0.32	3.8	0.35	0.32	3.8

[I] The test statistics are corrected for the number of variables in the model. For an explanation of the test statistics see Johansen (1995).

Dating of data is important when we test for exogeneity. If dated wrong, inference from tests could be disturbed by displacement of data. In this case data for the two price series should correspond exactly regarding timing except for the period after 1978 where the Danish data shifts to calendar year as opposed to being valid for the logging season. The influence from the discrepancy should be a bias towards showing Danish prices influencing Swedish prices and thus making it less likely to find significance for exogeneity in tests of the Swedish price.

Another explanation for the finding could be forward looking Danish roundwood market agents. If the price is adjusted in Denmark because of expectations of a specific future Swedish price development then data can be wrongly interpreted as if the Swedish price adjust to an imbalance in the long-run equilibrium whereas the true reason is creation of a deliberate imbalance by the Danish agents expecting the Swedish price to change and re-establish the equilibrium.

Finally, the model is used to produce 1-step ahead forecasts, depicted in Figure 2, for the Danish timber price. Estimations of the model indicate that the two demand variables modeling the short-run dynamics are too closely correllated to enter the system simultaneously. The estimation results reported in Table 3 are thus, based on the model including only the index for building activity, *BA,* and not *GNP%*.

TABLE 3. ESTIMATION RESULTS OF THE FORECAST MODEL IN EQ. (5).

Results are only reported for the equation for the Danish domestic timber price. The explanatory variables are building activity (BA) and a dummy variable for windthrow.

VARIABLE	COEFFICIENT	STD. ERROR	T-VALUE
$P_{SW,\ t-1}$	–0.145	0.083	–1.74
$P_{DK,\ t-1}$	0.200	0.088	2.28
$P_{SW,\ t-1}$	–0.339	0.123	–2.77
$P_{DK,\ t-1}$	0.609	0.141	4.31
Windthrow	–0.200	0.056	–3.55
Constant	0.269	0.166	–1.62
BA	0.114	0.042	2.73

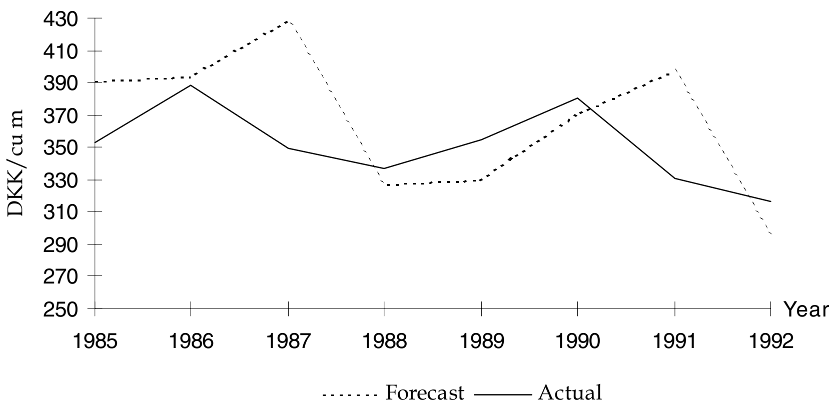

FIGURE 2. 1-STEP AHEAD FORECASTS 1985 THROUGH 1992 FOR THE DANISH TIMBER PRICE

A measure of stability of the model is the Chow test for parameter constancy over the forecast period. With a value of F(16, 24) = 1.38 [0.2334] it cannot be rejected that the coefficient vectors are the same also for the forecast period.

No attempt will be made as to statistically evaluate the quality of the produced forecasts. The model is used in Riis (1996) to plan for the terminal harvesting of Norway spruce stands and an increase in the profit of 2.6% is found. The procedure is based on 4-year dynamic forecasts over the period 1972 through 1992. The optimization algorithm does not operate with recourse which underestimate the potential in some 4-year periods.

CONCLUSION

The Danish price is shown to be cointegrated with the Swedish price indicating market integration. Weak exogeneity of the Swedish price with respect to the long-run parameters is rejected. A brief analysis of some of the features of the Danish timber market leads to a model where the demand side is represented through a variable for the percentage changes in GNP and an index for the building activity. Supply is only present through a dummy for a heavy windthrow in 1967.

The knowledge established in this paper and the forecasts produced should be combined with additional information outside the model. Among relevant factors are trends in end-uses of timber, current capacity in the industry, and annual potential supply from the forests. With the price series resembling random walks, the long-term projection is just the current level. Thus, it is only on a short term that the model offers some qualified predictions due to the dynamics of the adjustment process.

At last one could argue whether the model should be considered as a structural model, since the true variables are in fact never observed in a much more complex real world, or if the model should rather be concidered a mathematical forecasting model with some reasoning to the choice of specification.

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