Testing for Granger-Causality in the Finnish Roundwood Market

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Toppinen, A. 1997. Testing for Granger-causality in the Finnish roundwood market. Silva Fennica 31(2): 225–232.

The existence and direction of causal relationships between the time series for the Finnish roundwood market for the period 1960–1994 is tested. Using simple bivariate analysis, we found evidence that for both logs and pulpwood, the lagged prices are helpful in forecasting quantity for the next year, but not vice versa. Sawlog stumpage prices have significantly Granger-caused pulpwood prices over the business cycles, but the effect has diminished towards the present time. For quantities traded, the direction of causality was rather from pulpwood to sawlogs. The consistency of bivariate test results was checked by the Granger-causality tests within trivariate VAR-models for both markets, and the results were found to be fairly similar to bivariate tests. The price fluctuations in the international markets for forest products have been found to be carried to domestic wood markets dominantly via the pulpwood part of the market.

Keywords stumpage prices, roundwood market, Granger-causality, forecasting, time series analysis

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Accepted 17 April 1997

1 Introduction

The present paper reports on empirical testing of the existence of interdependencies between the key variables for the Finnish roundwood market. Motivation for the work is given by the need for developing short-term forecasting models for the Finnish wood market. Previous econometric studies of the sawlog and pulpwood markets in Finland include Kuuluvainen et al. (1988) and Hetemäki and Kuuluvainen (1992). Tervo (1986) studied structure and fluctuations of the aggregate roundwood market. However, none of these studies focused particularly on forecasting issues.

Although roundwood markets in different countries have been the topic of a number of economic studies, there are very few studies that explicitly test for causal effects. Buongiorno et al. (1985) considered testing for causality between lumber and stumpage prices and stumpage supply from the U.S. National Forests in 1962–84 and Uri and Boyd (1990) have researched the integration of four regional lumber markets in the U.S. by using causality tests. Considering the Finnish pulpwood market, Hetemäki and Kuuluvainen (1992) recognized causality running from pulpwood price to pulpwood quantity. However, they did not consider the sawlog part of the market, which accounts for about two thirds in total stumpage price earnings (Statistical yearbook of forestry 1996).

Following e.g. Brännlund et al. (1985) or Newman (1987), the disaggregation of the wood market into sawlog and pulpwood markets appears to be a good starting point for Finland as well. The setup for the market model for sawlogs and pulpwood can be found in Toppinen (1995) together with a more detailed description of recent changes in the market environment. It suffices to note here that we assume that a reasonable approximation of stumpage price determination in Finland is given by supply and demand factors, even though our study period includes an era of collective nationwide price recommendations (1978–1991) involving the Forest Industry Federation and the Federation of Forest Owners in Finland. Despite the price negotiations, there is evidence of market functioning since actual prices have not equaled recommended prices even during those years. Also, the negotiated stumpage prices were based to a great extent on export price developments for forest industry products, which are exogenous to producers in a small open economy such as Finland.

In this study Granger's direct causality test (1969) is used to investigate the bivariate causal ordering and possible feedback between the key variables of the roundwood market, i.e. stumpage prices and quantities and export prices of forest industry products. Because two-thirds of the sawnwood production and close to 90 percent of paper production are currently being exported from Finland, the export price and demand fluctuations represent the main source of external shocks to the Finnish forest sector. Implications of the results for further modelling and forecasting of Finnish roundwood market are discussed briefly.

2 Data and Methods

In modelling of the roundwood market in Finland, the most interesting causal relationships are those between prices and quantities of wood. As wood prices, we used stumpage prices since currently about 70 percent of the total volume of sawlog and pulpwood purchased from private forests originates from stumpage sales. Secondly, delivery prices (roadside prices) for logs and pulpwood fluctuate very much like to stumpage prices, but are less comparable to each other over the years.

As prices for forest industry products, we used export prices of coniferous sawnwood and prices of sulphate pulp. The link between sawnwood and sawlog prices is natural, since sawlogs are the main raw material input to the sawmill industry. For the derived demand for pulpwood, we have chosen pulp demand. Although the share of exports in pulp produced in Finland is currently small due to the integrated production of pulp and paper, pulp prices are clearly reflected in the prices of paper and paperboard products. Furthermore, due to strongly increased product diversification in the paper industry, it would be difficult to find a paper product that would remain as a homogenous product group during the whole study period, i.e. over three decades.

Annual stumpage price series for the felling years 1959/60 to 1993/94 were used for coniferous sawlogs (PSL) and pulpwood (PPW). The respective quantities purchased from private forests in millions of cubic meters were denoted as QSL and QPW. Data on stumpage prices and roundwood quantities were obtained from the Forestry Statistics of Finland. For export price variables, we used export unit value for coniferous sawnwood (SX) and sulphate pulp (CPX) as obtained from the Finnish customs statistics (FOB prices in Finnish marks). Since stumpage prices and quantities are not reported for calendar years, we had to simply assume, as in previous studies, that felling year 1993/94 is comparable to calendar year 1994 etc. Real prices were used, so that nominal prices were deflated by the wholesale price index, which is available in Official Statistics for Finland (Source: Statistics Finland).

To study the causal relationships between the time series, Granger-causality tests (Granger

1969) were calculated between stumpage prices and export prices of forest industry products and with respect to quantities of roundwood traded. In fact, Granger-causality tests can be better interpreted testing predictability between certain variables of interest. If knowledge of one time series results in smaller error variance in predicting another series than would result from using only the past information of another series, then the first time series is said to Granger-cause the other one.

Essentially, bivariate Granger-causality testing involves the use of F-tests to determine whether lagged values of a variable, say X, have any statistically significant contribution in explaining Y_t in addition to lagged Y_{t-j}. Thus, one is testing the null hypothesis $c_j = 0$ ($j = 1,\ldots K$) in

$$Y_t = a + \sum_{j=1}^{K} b_j Y_{t-j} + \sum_{j=1}^{K} c_j X_{t-j} + u_t \tag{1}$$

where u_t is assumed to be a well-behaved white noise error term (Granger and Newbold 1986).

The procedure is applied in the opposite direction to test the causality from Y to X. If Granger-causality proceeds in both directions simultaneously, there is feedback between the variables. When comparing asymptotic behaviour of eight different causality tests, Geweke et al. (1983) recommended the use of this regression-based F-test because it was found to perform well also in small samples.

In using the bivariate causality tests, it is not possible to rule out that results could be sensitive to the effects from omitted variables. For checking the consistency of bivariate results we calculated the same tests using multivariate VAR-models. In order to avoid problems concerning degrees of freedom, we chose to use separate VAR-systems for both pulpwood and sawlog markets. Restrictions testing Granger-causality were tested using the Wald test (see e.g. Greene 1993).

In general, time series that reflect forward-looking behaviour are often found to be predictors of economic time series. Instantaneous causality tests using X_t as an additional regressor, are sometimes used together with the ordinary Granger-causality test (e.g. Buongiorno et al. 1985). However, the logical conceptual framework for testing instantaneous causality has been questioned (Granger 1988). Instantaneous causality may be related to the small time delay between cause and effect compared to the time interval for which the data are collected, or to the case when truly causal variables are not included in the information set. In our case, if stumpage prices and quantities were determined simultaneously, an instantaneous causality test based on least squares estimation would also contain simultaneous equation bias. Due to these considerations, we did not test for instantaneous causality (see, however, Toppinen 1995).

The Granger-causality test is based on basic assumptions such as that individual variables are (weakly covariance) stationary and that there is no residual autocorrelation in the causality test regression. Sims et al. (1990) have shown that if the time series are nonstationary and contain unit roots, non-standard distributions should be applied in testing. Especially in the case where nonstationary time series are at the same time cointegrated, i.e. they exhibit similar co-movement over time, it is possible to test for non-causality with linear restriction in cointegration space, for example with Johansen's maximum likelihood approach (Johansen and Juselius 1992, Mosconi and Giannini 1992).

In the empirical section, we thus first tested for the existence of unit roots in all six variables by using both the standard Augmented Dickey Fuller test (hereafter ADF) and the Phillips-Perron version of ADF-test (Dickey and Fuller 1979, Phillips and Perron 1988). The null hypothesis for the tests is non-stationarity of a variable.

3 Results

Historically there have been strong cyclical fluctuations in stumpage prices and quantities in Finland (Fig. 1), originating mainly from the international markets for forest industry products. During the 1980s, the stumpage price recommendation system stabilized price fluctuations in Finland but not quantity fluctuations. In real terms, the sawlog price is at the same level in the 1990s as during the 1960s, while both the pulp-

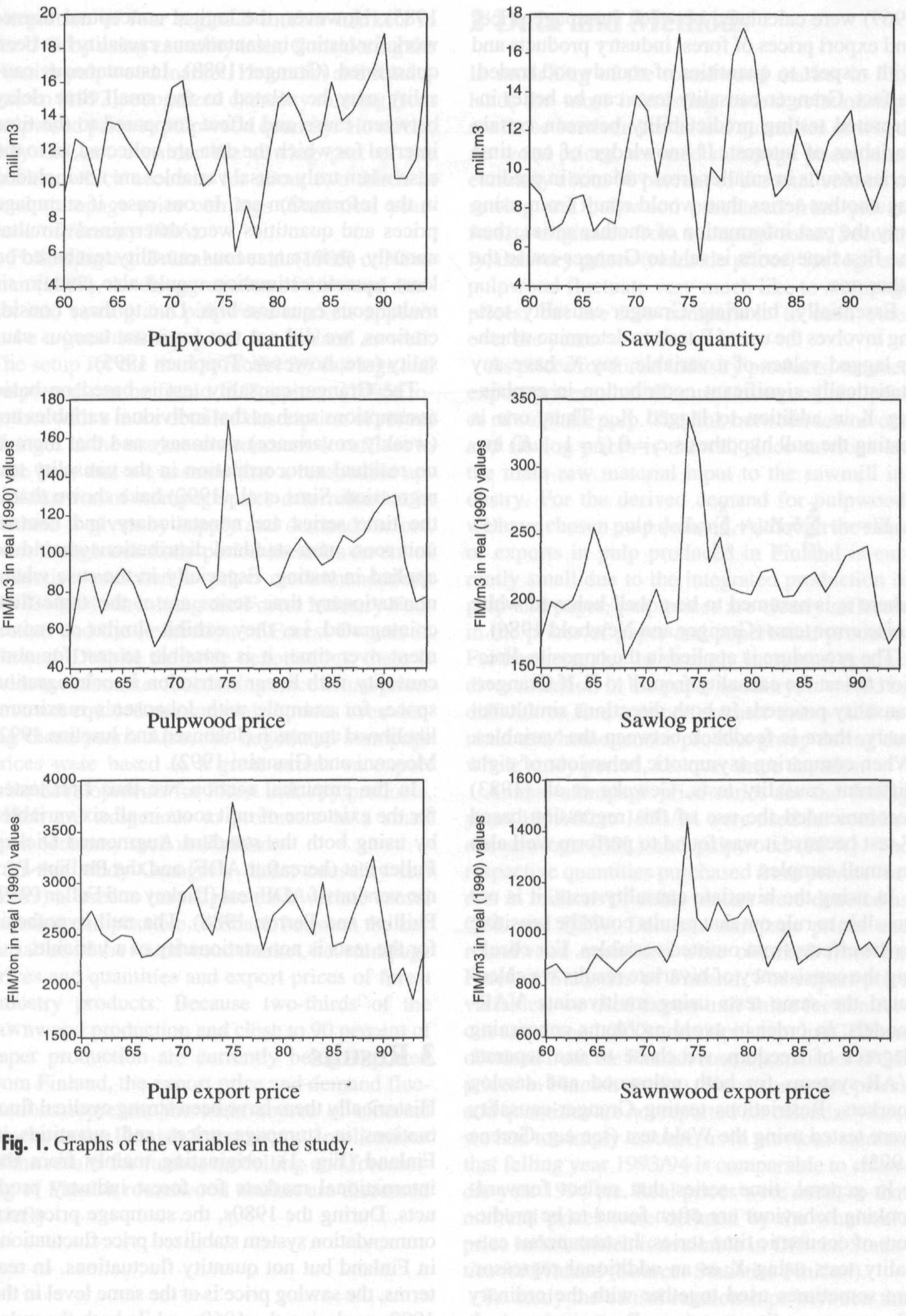

Fig. 1. Graphs of the variables in the study.

Table 1. Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) tests for the unit roots in individual time series. * indicates significance at 10 % level, ** at 5 % level and *** at 1 % level in the two tests.

	ADF-test (p = number of lags, constant term included)		PP-test (p = lag truncation)	
PPW Pulpwood price	–2.93*	(p = 0)	–3.07*	(p = 2)
PSL Sawlog price	–3.41**	(p = 1)	–3.30**	(p = 1)
QPW Pulpwood quantity	–3.38**	(p = 0)	–3.52**	(p = 2)
QSL Sawlog quantity	–3.71***	(p = 1)	–2.99**	(p = 2)
CPX Pulp export price	–3.39**	(p = 1)	–2.95**	(p = 2)
SX Sawnwood export price	–3.37**	(p = 0).	–3.04**	(p = 2)

Table 2. Granger-causality tests for period 1960–94. F-test values are for two lag models with the null hypothesis of non-causality, probability values given in the parentheses.

	F-statistic F(2,31)		F-statistic F(2,31)
PPW→PSL	1.11 (0.34)	PSL→PPW	**8.03** **(0.001)**
PSL→QSL	**12.5** **(0.0001)**	QSL→PSL	0.20 (0.82)
PPW→QPW	**9.79** **(0.001)**	QPW→PPW	0.27 (0.76)
QSL→QPW	2.68 (0.09)	QPW→QSL	**3.67** **(0.04)**
QSL→PPW	**5.50** **(0.001)**	PPW→QSL	**12.96** **(0.0001)**
QPW→PSL	0.59 (0.56)	PSL→QPW	**6.98** **(0.03)**
SX→PSL	1.34 (0.28)	PSL→SX	1.90 (0.17)
SX→QSL	1.02 (0.98)	QSL→SX	0.12 (0.88)
CPX→PPW	2.87 (0.07)	PPW→CPX	0.67 (0.51)
CPX→QPW	**3.89** **(0.03)**	QPW→CPX	0.43 (0.65)

wood price and quantity variables exhibit a slightly rising trend.

Before proceeding to the Granger-causality test, we checked the assumption that the time series are stationary. Both the Augmented Dickey Fuller and Phillips-Perron tests indicated that non-stationarity should not be a problem in our data (Table 1). The null hypothesis of unit root could be rejected at the 5 percent level for all the time series except for pulpwood stumpage price, for which it was rejected at the 10 percent level. We proceeded under the assumption that all our variables are stationary, and used the levels of logarithmic variables in testing for causality.

The Granger-causality tests were performed using lags of 1 to 3 years in the test equations. In general, the test results were robust for different lags. The F-form of the Lagrange-Multiplier test, which is valid for systems with lagged dependent variables (see e.g. Greene 1993), was used to examine that there was no autocorrelation in the residual term of the test equation. Since there was in general no indication of residual autocorrelation left in the regression equation with $j = 2$, we present in Table 2 the results for the causality tests using two lags.

The results from Granger-causality tests indicated significant one-way causality from both stumpage prices to roundwood quantities traded, but feedback from traded quantities to their own prices was absent. Furthermore, there appeared to be linkages between the two wood markets: the sawlog stumpage price helped to forecast the pulpwood stumpage price over autoregressive pulpwood price forecasts. On the other hand, with the two wood quantities, the causality was running from pulpwood quantities to sawlog quantities. Sawlog quantity helped to forecast the pulpwood stumpage price, which could be due to the fact that business cycles in the sawmilling industry have often been leading the fluctuations in the pulp and paper industry.

Table 3. Granger-causality tests for the exclusion of variables in rows from VAR (p = 3, k = 2) model for sawlog market, with probablity values given in the parentheses.

	1960–94 Granger-causality to			1960–77 Granger-causality to			1978–1994 Granger-causality to		
	PSL	QSL	SX	PSL	QSL	SX	PSL	QSL	SX
PSL	–	**41.80**	4.78	–	**22.59**	**7.14**	–	**11.73**	2.03
		(0.00)	(0.09)		**(0.00)**	**(0.03)**		**(0.02)**	(0.36)
QSL	0.38	–	1.34	0.10	–	1.98	1.86	–	2.87
	(0.83)		(0.51)	(0.95)		(0.37)	(0.39)		(0.36)
SX	2.48	**9.83**	–	1.84	**10.22**	–	1.81	0.95	–
	(0.29)	**(0.01)**		(0.40)	**(0.01)**		(0.41)	(0.62)	

Table 4. Granger-causality tests the exclusion of variables in rows from VAR (p = 3, k = 2) model for pulpwood market, with probablity values given in the parentheses.

	1960–94 Granger-causality to			1960–77 Granger-causality to			1978–1994 Granger-causality to		
	PPW	QPW	CPX	PPW	QPW	CPX	PPW	QPW	CPX
PPW	–	**12.78**	2.22	–	**13.64**	0.76	–	**9.82**	4.24
		(0.01)	(0.33)		**(0.01)**	(0.68)		**(0.01)**	(0.12)
QPW	1.30	–	1.76	2.40	–	1.11	**25.60**	–	2.09
	(0.52)		(0.41)	(0.30)		(0.57)	**(0.01)**		(0.35)
CPX	**6.28**	3.17	–	4.52	3.23	–	**10.7**	**6.74**	–
	(0.04)	(0.20)		(0.10)	(0.20)		**(0.01)**	**(0.03)**	

Quite surprisingly, lagged export prices of forest products did not contribute significantly in explaining stumpage prices of either sawlogs or pulpwood. However, pulp export prices were found to significantly cause pulpwood quantity. Our interpretation to this result is that the pulpwood market is the channel through which the shocks in the export markets have been carried to domestic wood markets.

In order to take account the possible problems arising from omitted variables in bivariate tests, we tested for the Granger-causality in both submarkets also using three variable VAR-systems. Secondly, as a check to whether the results for causality tests are sensitive to the specific data period, we performed the same set of tests with the sample period divided into two subperiods. Results for the total sample and for subperiods 1960–77 and 1978–94 are presented in Tables 3 and 4.

Significant causality from stumpage prices to quantities was detected, but no feedback effect was found for the period 1960–94, when the VAR-models were used. However, during the latter period in 1978–94, two-sided causality was detected between pulpwood stumpage prices and quantities. Also, Granger-causality running from pulp export prices to pulpwood stumpage prices was detected in 1960–1994. This effect was even more clearly present in the market during the latter half of the sample period. In addition, the pulp price was found to help in forecasting the pulpwood quantity in 1978–94.

In sawlog market system, stumpage prices were found to cause quantities throughout the whole period. However, the other causal relations in the sawlog system were again less in accordance what could be expected. Sawnwood export price was found to Granger-cause sawlog quantity, but the effect was no longer present during the second half of the sample. Quite unexpectedly, the sawlog quantity was found to Granger-cause sawnwood price, but only in the first half of the sample.

4 Discussion

In this study, direction and significance of Granger-causality were examined in the Finnish stumpage market. The results are useful as background information for building econometric short-term forecasting models for the roundwood market. However, the shortcoming of the approach is that it does not measure the relative strength of the relationship. As such, the causality tests should be rather viewed as tests of whether one variable helps in forecasting another variable rather than as strict tests of causation. One-way causality from stumpage price to quantity is not, however, sufficient evidence for the use of least squares estimation in behavioral models, since Granger non-causality does not test simultaneity. Despite the fact that we used three variable VAR-models to check the consistency of bivariate causality tests, possible effects due to omitted variables should be borne in mind.

Disaggregation of the stumpage market into two submarkets enabled us to study the interdependencies between the two main assortments, i.e. sawlogs and pulpwood. Sawlog price was found to cause pulpwood price, but the effect weakened towards the present time. For both sawlogs and pulpwood, there was evidence of one-way causality from stumpage prices to wood quantities.

The Granger-causality tests indicated relatively weak causality running from sawnwood export markets to sawlog markets. The effects were more clearly present in the pulpwood part of the market, where Granger-causality from pulp prices to both pulpwood prices and quantities was found in period 1978–94. One explanation for the lack of strong causality from export prices to stumpage market could be found in the rough aggregation of the stumpage market into sawlog and pulpwood sectors, while in fact different wood species in the two wood assortments are used for certain differentiated products, and are not perfect substitutes for each other.

Also, some changes in causality patterns were revealed in comparing the two subperiods, i.e. 1960–77 and 1978–94. For example, two-sided causality, i.e. feedback between the price and quantity of pulpwood in the period 1978–94 was found. This indicates that the dynamics of the pulpwood market probably have changed during the study period. One plausible explanation for this could be the stumpage price recommendation system, which was in effect during most of the second period. However, studying this phenomenon explicitly requires other econometric tools than used in this paper, and has to be left for another study.

Due to changes in causality patterns over time, there may also be problems in obtaining stable parameter estimates for demand and supply models by using data that extends from the 1960s to the mid-1990s. Consequently, the development of short-term forecasting models should perhaps be directed towards the use of data covering shorter time spans and higher frequency, i.e. quarterly or monthly data. In this way we could also hope to learn more about the short-run dynamics between the markets for forest products and roundwood in Finland.

Acknowledgements

I thank Jari Kuuluvainen, Mikko Tervo and two anonymous referees for comments on earlier versions of this paper. Financial support from Academy of Finland and Metsämiesten säätiö is acknowledged.

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