# COINTEGRATION IN FINNISH PAPER EXPORTS TO THE UNITED KINGDOM

**SUSANNA LAAKSONEN, ANNE TOPPINEN, RIITTA HÄNNINEN AND JARI KUULUVAINEN***

*ABSTRACT*

*This paper investigates short- and long-run export demand for Finnish printing and writing paper (excluding newsprint) in the United Kingdom. Empirical demand equations based on the Armington export demand model are estimated using quarterly data from the UK foreign trade statistics and cointegration and error-correction methods. For uncoated paper, the long-run price elasticity and the elasticity of Finnish exports with respect to total imports is estimated and short-term adjustment explained using an error-correction model. For coated paper the long-run relationship predicted by the Armington model does not get empirical support, and a short-run export demand model using first differences of the variables is estimated.*

*Keywords: cointegration, export demand, paper.*

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## INTRODUCTION

Finnish forest industry products are exported mainly to Western Europe, the United Kingdom being the most important single export market. In Finland, over 80 % of the export income of the forest industries is derived from the pulp and paper industry. The export income of the forest industries accounts for just under 40 per cent of Finland's total export earnings. Therefore, reliable forecasts of export demand have practical importance and can be utilized, for example, in making annual short-run forecasts for the Finnish forestry sector.

The demand for pulp and paper products has been investigated earlier by either assuming perfect competition, in which case relative costs matter (e.g. Brännlund *et al.* 1982; Buongiorno & Gilles, 1984), or by assuming imperfect competition, in which case relative product prices are

* Susanna Laaksonen, Anne Toppinen, Riitta Hänninen and Jari Kuuluvainen, Finnish Forest Research Institute, Helsinki Research Centre,Unioninkatu 40 A, 00170 Helsinki, Finland.

the key determinants of exported quantities. Studies assuming imperfect competition in forest products' trade have often applied Armington's (1969) approach to modelling export demand (e.g. Carlén *et al*., 1984; Chou & Buongiorno, 1983; Chou & Buongiorno, 1984 and Blatner, 1989). In Finland, Volk (1983) has used the Armington approach to model exports of Finnish printing and writing paper to the United Kingdom and Germany while Hänninen (1986) has studied the demand for Finnish sawnwood exports.

None of the above-mentioned studies on export trade in forest products uses the multivariate maximum likelihood approach developed by Johansen (1988) and Johansen & Juselius (1990 and 1992) which is presently the only method that can be used to study cointegrated systems. Further, the advantage of this method is that the long-run relationships between the theoretically justified nonstationary variables of the model can be tested in a multivariate case using $\chi^2$ distribution.

In this paper Johansen and Juselius cointegration techniques and error-correction methods are used to examine long- and short-run effects of relative prices on export demand. We also test the constant long-run market share hypothesis implied by the Armington export model. The paper is organized as follows. In the next section, the Armington export demand model based on two-stage budgeting is briefly described. The empirical methods are presented in section three and the results in section four, followed by conclusions in section five.

## Export Demand

The Armington export demand model is based on the two-stage budgeting procedure used in modelling the demand for consumer goods. Accordingly, the consumer is assumed to allocate his budget in two stages (see e.g. Deaton & Muellbauer, 1980). In the first stage, the consumer decides on aggregate commodity groups (e.g., food, housing, entertainment), and in the second stage expenditures are allocated over individual commodities. Two-stage budgeting is possible if the direct utility function is homothetic and weakly separable into aggregate commodity groups.

In the Armington export demand model, the two-stage budgeting process implies that export demand e.g. for a paper grade can be assumed to be derived from the production function of industrial end-users. The importer's production function is assumed to be homothetic and weakly separable in aggregate categories of inputs (coated paper, uncoated paper, labor, capital, etc.). Furthermore, it is assumed that a product from an aggregate input group originating from a supplier country is not a perfect substitute for the same product originating from another supplier country. Because of weak separability, the marginal rate of substitution between products within an aggregate input group (for example, a certain paper grade from different countries) is independent of the use of other inputs. Moreover, as the production function is homothetic, only changes in relative prices can change market shares of supplier countries' paper. Following Alston *et al*. (1990), the two-stage allocation of export demand can be explained as follows. In the first stage, the representative importer of a country decides on the total imports of a particular product group

$$X = X(Y, P, P_0), \tag{1}$$

where $X$ is total imports of, say, coated paper to the importing country from all exporters, $Y$ is the importer's income, $P$ is the price of coated paper and $P_0$ is the price index of the other inputs.

In the second stage, total imports of the product group, e.g. coated paper, are allocated between the supplier countries. Thus, coated papers from different supplier countries are considered to be different products. In general form, the export demand for coated paper from country i is written

$$X_i = X_i(X, P_1, \ldots, P_n), \tag{2}$$

where $X_i$ is imports of coated paper from country $i$ ($i$ = 1,..., $n$) and $P_i$ is the respective import price from country $i$. Because the Armington model uses the constant elasticity of substitution (CES) within-group specification for equation (2), we can write the demand for country $i$'s coated paper as

$$X_i = (\gamma_i)^{\sigma} X(P_i/P)^{(1-\sigma)}, \tag{3}$$

where $X_i$ is, for example, Finnish exports to the UK and $X$ is total exports of coated paper to the UK (i.e. UK imports from all supplier countries), $P_i$ is the Finnish export price (i.e. price of Finnish coated paper imported into the UK), $P$ is the UK import price index for coated paper, depending only on within-group prices and $\sigma$ is the constant elasticity of substitution parameter. The model specification assumes that the elasticity of substitution ($\sigma$) for each pair of supplier's products is identical. Equation (3), in logarithmic form, is the static form of the equation used in this study to estimate long-run demands for two paper grades.

The Armington model, which uses quantities instead of cost shares, has been criticised for introducing an approximation bias into the empirical analysis if the demand functions are derived from the expenditure minimization problem (Davis & Kruse, 1993). Alston *et al*. (1990) addressed both homotheticity and separability and their empirical results rejected both of these assumptions in the case of agricultural commodities. In spite of its possible weaknesses, we consider the Armington model to be a useful starting point for practical forecasting. The constant market share assumption, i.e. that of unitary elasticity of Finnish exports to the UK with respect to total UK imports, can be tested for both the long and short-run. However, it must be remembered that economic theory in general, and thus also the Armington model, is about long-run relationships. Therefore, the theory does not actually provide hypotheses for the signs or magnitudes of the coefficients of the empirical short-run model.

## ESTIMATION PROCEDURE

Johansen's multivariate maximum likelihood procedure (Johansen, 1988; Johansen & Juselius, 1990; 1992) is applied to test for cointegration among the variables and for the constant market share assumption of the Armington model. In the presence of cointegration, the error-correction model (ECM) can be used to describe the short-term dynamics. As ECMs are standard tools in applied econometrics, it suffices to refer the interested reader e.g. to Davidson *et al*. (1978), Hendry *et al*. (1990) and Banerjee *et al*. (1993).

In the Johansen procedure the basic statistical model is a $p$ -dimensional VAR($k$) process:

$$x_t = \mu + \Pi_1 x_{t-1} +,\dots,+ \Pi_k x_{t-k} + \Phi D_t + \varepsilon_t, \quad t = 1,\dots,T \tag{4}$$

where $x_t$ is a $(p \times 1)$ column vector that denotes the $t$'th ($t$ = 1,...,$T$) observation on a set of $p$ variables, $\mu$ is a $(p \times 1)$ vector of constant terms, $D_t$ is a seasonal dummy, $k$ is the lag length, $P_1,\dots, P_k$ are $(p \times p)$ coefficient matrices and $\varepsilon_t$ is a $(p \times 1)$ vector of normally and independently distributed error terms with expectation zero. Any $k$th order VAR in levels represented in (4) can be reparameterized into error-correction form:

$$\begin{aligned}&\Delta x_t = \Gamma_1 \Delta x_{t-1} +,\dots,+ \Gamma_{k-1} \Delta x_{t-k+1} + \Pi \Delta x_{t-k} + \mu + \Phi D_t + \varepsilon_t, \\ &t = 1,\dots T,\end{aligned} \tag{5}$$

where $\Delta x_t$ is an $I(0)$ vector and $\Gamma_1,\dots, \Gamma_{k-1}$ and $\Pi = -I + \Pi_1 + \Pi_k$ are coefficient matrices, and the error vector is assumed to be NID(0,$\Omega$) as in (4). The $(p \times p)$ matrix $\Pi$ determines whether the model system is cointegrated. In our case, model (5) is a three-dimensional system including equations for Finnish exports to the UK, total UK imports and relative price, for both paper grades. The parameters to be estimated are $\Gamma = (\Gamma_1, \dots, \Gamma_{k-1}, \mu)$ and $\Pi = \alpha\beta'$. The columns of the $(p \times r)$ matrix $\beta$ are the cointegration vectors (long-run relations) and $\alpha$ is the $(p \times r)$ matrix of the respective factor loadings.

The rank, $r$, of the matrix $\Pi$ determines the number of cointegrating vectors. When all $p$ components (variables) of $x_t$ are stationary, matrix $\Pi$ has full rank, i.e. $r = p$. When the variables are integrated but not cointegrated ($r$ = 0), the model should be respecified in differences (Banerjee *et al*., p. 256). If $0 <$ rank $(\Pi) = r < p$, $\alpha$ and $\beta$ are $(p \times r)$ matrices such that $\Pi = \alpha\beta'$ is of reduced rank. This means that the system is cointegrated and the rank of the matrix $\Pi$ is the number of cointegration vectors. Although the stationarity of individual series is checked inside the model rather than determined prior to the analysis (Johansen, 1995, p. 74; see also Hamilton 1994, p. 645), we have also performed the traditional ADF-tests before testing for cointegration (Dickey & Fuller 1979).

The number of cointegration vectors is unknown and must be determined from the data. The Johansen method entails two tests for the number of cointegrating vectors, $r$:

the trace and the maximum eigenvalue tests (see e.g. Johansen, 1995, pp. 93–94). The likelihood ratio test for the null hypothesis, $H_0 : r = r_0$ against $H_1 : r_0 < r \leq p$, is a trace test. When the estimated value of the trace test is smaller than the critical value, the null hypothesis that there are at most $r_0$ cointegrating vectors can be accepted. In the maximum eigenvalue test, the null hypothesis is $H_0 : r = r_0$ against $H_1 : r_0 = r_0 + 1$.

Having estimated the cointegrating vectors, it is possible to test hypotheses under $r$, using the likelihood ratio test and imposing restrictions on the matrix of cointegration vectors, $\beta$, or the matrix of loadings, $\alpha$. The test statistics are asymptotically $\chi^2$ distributed. We test the constant market share assumption (unit elasticity of Finnish exports with respect to total exports at given prices) and the stationarity of the variables and examine if the price variable can be excluded from the long-term relationship. These tests are made by restricting $\beta$.

In the present study $r$ was found to be one. With $r = 1$, the constant market share, i.e. unitary elasticity of exports with respect to total imports, can be tested with the following linear restriction on $\beta$:

$$\beta = H\varphi = \begin{bmatrix} 1 \\ -1 \\ 0 \end{bmatrix} \varphi, \tag{6}$$

where $H$ is a design vector that formulates the restriction on $\beta$ and $\varphi$ is an $(s \times r)$ matrix, where $r \leq s \leq p$ and $s$ is the number of restrictions (see e.g. Johansen & Juselius, 1990). Thus, restriction (6) imposes the constant market share assumption, i.e. it is tested whether the coefficients of paper exports from Finland to the UK and total UK paper imports can be restricted to [1,–1] in the cointegrating vector.

Finally, we examine whether the relative price can be excluded from the cointegration vector. This means we test a zero restriction on the coefficient of relative price in the cointegration vector. Accepting the restriction would imply that the relative price does not affect the long-run development of Finnish paper exports to the UK.

## DATA AND EMPIRICAL RESULTS

### *Cointegration and Long-run Elasticities*

In this section we report the empirical results for the long- and short-run relationships of Finnish exports of coated and uncoated paper to the United Kingdom. Coated and uncoated printing and writing paper are studied separately. Together they account for 70 per cent of chemical forest industry exports from Finland to the United Kingdom.[1] The study uses quarterly data in quantities (1000 tons) and unit values (£/ton) for total UK imports of both product groups and for UK imports from Finland. The observation period is 1976–1992 and consists of 68 quarterly observations.[2] The models are estimated using quarterly data for the period 1976(3)–1990(4), leaving 8 quarters to test out-of-sample forecasting performance.

The stationarity of the variables is tested before estimation by the Augmented Dickey-Fuller (ADF) test (Dickey & Fuller, 1979). The results presented in Table 1 indicate that all variables are nonstationary in levels. Next, the statistical VAR-system (equation 5) consisting of three equations for each of the two paper grades is estimated. The diagnostic tests for the VAR-estimations are reported in Table 2.

For coated paper, the one-lag structure is adequate, producing non-autocorrelated and normally distributed error terms. The autocorrelation of the residuals is examined by means of the Lagrange multiplier (LM) test, which is valid for systems with lagged dependent variables. Normality of the residuals was tested with the Doornik-Hansen test. For testing details and references, the reader is referred to Doornik and Hendry (1994).

[1] Perhaps a better approach from the end user's point of view would have been to divide printing and writing paper into wood-containing (mainly magazine paper) and wood-free (fine paper) grades. The UK trade statistics, however, do no allow such a distinction.

[2] The relative price is the unit value of imports from Finland divided by the average unit value of the products of other exporters. For the average unit value of uncoated paper of other exporters and total imports, interpolated observations had to be substituted for outlier observations in the late 1980s that were due to obvious errors in the trade statistics (also classification changes occurred during the late 1980s).

TABLE 1. TIME SERIES TESTS OF INDIVIDUAL VARIABLES.
*Normality and unit root tests (ADF-tests with constant, trend and four lags). Critical values at 5 % level 5.99 and –3.48, respectively.*

| VARIABLES T = 66 | NORMALITY TEST $\chi^2(2)$ | ADF LEVELS | ADF FIRST DIFFERENCES |
|---|---|---|---|
| *Coated paper* | | | |
| Imports from Finland | 7.07* | –2.45 | –3.82* |
| Total imports | 5.32 | –3.15 | –4.10* |
| Relative price | 1.39 | –1.53 | –4.81* |
| *Uncoated paper* | | | |
| Imports from Finland | 45.73* | –2.47 | –5.26* |
| Total imports | 8.35* | –2.59 | –5.00* |
| Relative price | 31.32* | –2.40 | –5.99* |

For uncoated paper, the residuals fail the $\chi^2$ -test for normality due to outliers, and in the case of total imports there is some evidence of possible autocorrelation. Also, the residual standard errors in the models for uncoated paper are fairly large. However, as the use of longer lags, up to 4 quarters, did not improve the diagnostic test results, we retained the one-lag system.

The Johansen cointegration tests (Table 3) do not detect cointegration between total UK imports, UK imports from Finland and the relative price of coated paper. The trace-test statistics falls below the 10 % critical value. This means

TABLE 2. STATISTICAL MODELS.
*Residual test statistics for the statistical models for coated and uncoated paper (number of lags one, seasonals included), 1976:3– 1990:4.*

| | COATED PAPER | | | UNCOATED PAPER | | |
|---|---|---|---|---|---|---|
| Test statistic | Imports from Finland | Total imports | Relative price | Imports from Finland | Total imports | Relative price |
| Auto-correlation LM(4)[i] | 4.28 | 6.23 | 4.47 | 6.35 | 11.85* | 4.12 |
| Normality[ii] | 2.61 | 4.96 | 4.86 | 25.67* | 20.84* | 12.61* |
| $\sigma$[iii] | 0.12 | 0.10 | 0.04 | 0.23 | 0.17 | 0.07 |

[i] Critical value $\chi^2$ (4) 9.49
[ii] Critical value $\chi^2$ (2) 5.99
[iii] Standard error of regression

TABLE 3. COINTEGRATION TESTS.
*Results of the cointegration rank tests (r = hypothesized number of cointegrating relations, λ = size of eigenvalue)*

| VARIABLES | $H_0$: *r* | λ | TRACE TEST STATISTICS | MAX λ TEST STATISTICS | CRITICAL VALUES TRACE/MAX λ (5 %) |
|---|---|---|---|---|---|
| Coated | | | | | |
| paper model | 0 | 0.19 | 22.84 | 12.35 | 34.9 / 22.0 |
| ($p$ = 3) | ≤ 1 | 0.14 | 10.5 | 8.93 | 20.0 / 15.7 |
| | ≤ 2 | 0.03 | 1.57 | 1.57 | 9.2 / 9.2 |
| Uncoated | | | | | |
| paper model | 0 | 0.36 | 45.04* | 25.56* | 34.9 / 22.0 |
| ($p$ = 3) | ≤ 1 | 0.21 | 19.48 | 13.94 | 20.0 / 15.7 |
| | ≤ 2 | 0.09 | 5.53 | 5.53 | 9.2 / 9.2 |

that the respective series are non-stationary, but not cointegrated. We conclude that there appears to be no statistically significant long-term relationship between Finnish exports of coated paper, total UK imports of coated paper and the respective relative price. This may indicate competitive markets for coated paper in the UK, in which case imports from supplier countries are in the long-run determined by production costs at the given market price.

For uncoated paper, the hypothesis of one cointegrating relationship is accepted (Table 3). The estimated coefficients (long-run parameters) of the unique cointegration relation, ($\beta_{11}$, $\beta_{21}$, $\beta_{31}$), and the respective factor loadings, ($\alpha_{11}$, $\alpha_{21}$, $\alpha_{31}$), i.e. the error-correction parameters, are presented in Table 4. The loading of the relative price is small (–0.02) which means that this variable may not be necessary in the relation and so testing is required.

The constant market share assumption is tested estimating an unrestricted model and a model in which the coefficients of $X_i$ and $X$ are restricted to be of same size, but of opposite sign (i.e. $\beta_{11} = -\beta_{21}$) in the cointegration vector. The test statistic is asymptotically $\chi^2$ distributed. According to the results the restriction is accepted (Table 4). The restricted long-run equilibrium relation, $\beta_1$, for imports of uncoated paper from Finland can presented as

$$1.00X_i = 1.00X - 0.75(P_i/P) + 0.8c, \qquad (7)$$

where $X_i$ is imports from Finland to the UK, $X$ is total imports of uncoated paper to the UK (i.e. UK imports from all supplier countries), $P_i$ and $P$ are the respective prices and $c$

TABLE 4. COINTEGRATING VECTORS AND RESTRICTION TESTS.
*Estimated eigenvectors $\beta_i$ and the corresponding $\alpha$–weights for uncoated paper for unrestricted and restricted models. Restriction tests are: (1.) Armington hypothesis and (2.) excluding relative price from cointegration space.*

| Explanatory variables | Unrestricted Model | | | Restricted Model | LR–test Value[i] | |
|---|---|---|---|---|---|---|
| | Eigenvectors | | | $C_i$–vector | Armington[ii] hypothesis | Price[iii] exclusion |
| | $\beta_{i1}$ | $\beta_{i2}$ | $\beta_{i3}$ | $\beta_{i1}$ | | |
| Imports from Finland | 1.00 | –0.70 | 0.56 | 1.00 | | |
| Total imports | –0.87 | 1.00 | –0.95 | –1.00 | 2.28 (p = 0.13) | |
| Relative price | 1.00 | 2.98 | 1.00 | –0.75 | | 4.29* (p = 0.04) |
| Constant | –0.75 | –3.24 | 5.13 | –0.80 | | |
| | Loadings | | | | | |
| | $\alpha_{i1}$ | $\alpha_{i2}$ | $\alpha_{i3}$ | $\alpha_{i1}$ | | |
| Imports from Finland | –1.01 | –0.01 | 0.22 | –1.00 | | |
| Total imports | –0.47 | –0.06 | 0.25 | –0.38 | | |
| Relative price | –0.02 | –0.10 | –0.03 | 0.02 | | |

[i] The 5 % critical value for a $\chi^2(1)$ test is 3.84.
[ii] $H_0$ : $[\beta_{11}, \beta_{21}] = [1, -1]$
[iii] $H_0 : \beta_{31} = 0$

is a constant. The long-run coefficients are of expected sign, implying that an increase in total import demand to the UK increases import demand from Finland and an increase in Finnish relative price decreases it.

The exclusion test for the relative price is done by testing whether its coefficient ($\beta_{31}$) in the cointegration vector can be restricted to zero. Again the test statistic is asymptotically $\chi^2$ distributed. The restriction is rejected (Table 4), indicating that the relative price must be included, as the theory predicts.

### *Short-run Export Demand Models*

As the individual time series for coated paper appear to be integrated but not cointegrated, only the short-run export demand model can be estimated using first differences of the variables. The results with diagnostic tests are presented in Table 5. The Lagrange multiplier (LM) test of no autocorrelation against fourth-order residual auto-correlation is accepted. Also the null hypothesis of no heteroskedasticity can be accepted. The normality test (Doornik-Hansen test statistic) accepts the residual normality. Model specification is tested by the forecast test $\chi^2(8)$. According to the results, the null hypothesis of no parameter change between sample and forecast periods can be accepted. Consequently, the short-run model, including the constant term, behaves well statistically.

For coated paper, the short-run elasticity of total Finnish exports to the UK with respect to total UK imports is 0.98 and the coefficient restriction to unity can be accepted by the Wald test. Thus, the constant market share hypothesis seems to hold for the short run for coated paper. The short-run elasticity of export demand for coated paper with respect to the relative price is –0.48, but it is not statistically significant at the 5 % level.

TABLE 5. SHORT–RUN MODELS.

*Short–run error–correction model for coated and uncoated paper, differenced form (t–values in parenthesis).*

| | COATED PAPER | UNCOATED PAPER |
|---|---|---|
| Constant | –0.00<br>(–0.21) | 0.00<br>(0.04) |
| Total imports | 0.98<br>(7.68) | 1.14<br>(14.24) |
| Relative price | –0.48<br>(–1.51) | –0.44<br>(–2.19) |
| ECT(–1) | | –0.52<br>(–4.45) |
| $R^2$ | 0.54 | 0.85 |
| F | 32.16 | 98.2 |
| DW | 2.46 | 2.36 |
| LM(4)[ii] | 1.64 | 3.54 |
| JB (2)[i] | 0.01 | 28.79 |
| ARCH[ii] | 2.19 | 1.31 |
| $\chi^2(8)$[iii] | 7.9 | 14.42 |

Critical values at 5 % level:
[i] Normality $\chi^2(2)$ 5.99
[ii] Autocorrelation and heteroskedasticity f(4, 50) 2.56
[iii] Forecast $\chi^2(8)$ 15.51

For uncoated paper, one cointegrating vector was detected. Using this as an error-correction term, the ECM for uncoated paper was estimated. Diagnostic tests indicate non-normality and fourth-order autocorrelation (Table 5). However, it seems that non-normality is due to the large fluctuations in the time series of uncoated paper exports in the beginning of the period, and not to misspecification of the model. For uncoated paper, the constant market share hypothesis is accepted in the long run model as well as in the short- run model. As one would expect, imports are less elastic with respect to price in the short run than in the long run. The model fit ($R^2$) is 0.85, better than in the short-run model for coated printing and writing paper.

We do not consider the forecasting properties of the models in *I*(1) space because our interest is mainly in short-run forecasting. Moreover, we were unable to estimate the long-run relationship for coated paper. Table 5 reports the test statistics for one-step-ahead out-of-sample forecasts for both Armington models in differences. The Chow F-test indicates acceptable out-of-sample forecasting performance for both paper grades. According to the graphs in figures 1 and 2 in the appendix, the Armington models perform relatively well also in predicting turning points in the data.

## CONCLUSIONS

This paper has investigated the long- and short-run import demand for two Finnish paper grades, coated and uncoated paper, in the United Kingdom. An important result is that the same theoretical model does not receive empirical support even for two rather similar products.

We were unable to find a statistically significant long-run relationship for Finnish exports of coated paper to the UK. This may be an indication of a competitive market structure, in which case imports are determined by production costs in the countries of origin. The short-run export demand model for coated paper passed all the diagnostic tests. However, even in the short run, the elasticity of imports with respect to the relative price was not statistically significant.

For uncoated paper, a unique long-run relationship between Finnish exports to the UK, total UK imports and the relative price was found and the Armington hypothesis of constant market share, given the relative price, was accepted both in the short and long-run. The error-correction term was statistically significant and indicated that the adjustment to the long-run level takes about two quarters.

The Armington model thus seems to describe well the export demand for uncoated paper. We conclude that the Armington modelling approach of imperfect competition is more suitable for uncoated paper. The Finnish market share, about 50 per cent in the UK uncoated paper market, is clearly higher than in the market for coated paper. The market structure supports the estimated results, indicating that competition is less perfect for uncoated paper than for coated paper in the UK market.

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## Appendix

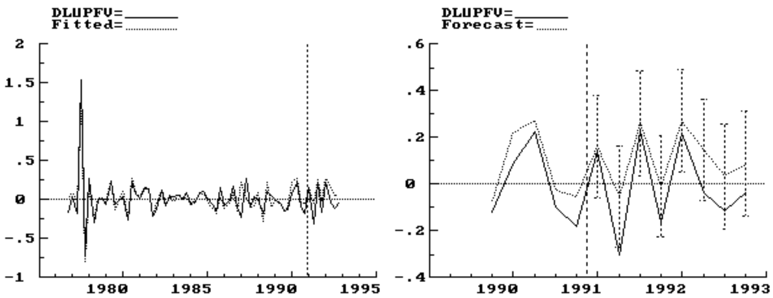


Figure 1. Short-run Export Demand Model and One-step-ahead out-of-sample Forecasts for Uncoated Paper

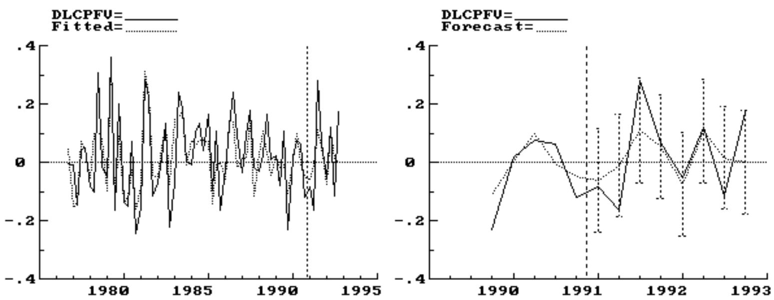


Figure 2. Short-run Export Demand Model and One-step-ahead out-of-sample Forecasts for Coated Paper