THE EXPORT-PRODUCTIVITY RELATIONSHIP:

A TIME SERIES REPRESENTATION FOR AUSTRIA

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Content

1. Introduction

The causes of the wide variation in growth rates between countries have been debated by theorists of economic growth. Different studies have shown these disparities between growth rates to be only in part explainable by different rates of increase in the employment of the basic factors of production, capital and labour (Solow 1957, Denison 1967). The main conclusion to be drawn from these studies is that the diversity in growth rates between countries was largely caused by different rates of increase in productivity per unit of factor input. The observed positive association between productivity growth and export growth led to two contrasting causal hypotheses. The first assumes technical change and productivity to be largely induced by demand prospects via export growth, which is initially autonomous. The second considers technical change and productivity to be mainly autonomous in the sense of being relatively independent of export demand and it is then the rate of growth of exports which is determined by supply factors like technical innovation.

The direction of causation between exports and technical change has important implications for the way economic policy can stimulate growth. While the export-productivity link given by the export-led growth model suggests a demand policy to push exports up, e.g. by a depreciation of the exchange rate, the link described by the technology based international trade models considers supply measures like encouragement of R&D expenditures, subsidies for investments in innovation etc. as more effective to stimulate growth.

This paper explores with Austrian data which of the above hypotheses are compatible with the observed movements between exports, productivity and the terms of trade. For that purpose, the causal ordering between exports, productivity, and the terms of trade will be identified on the basis of Granger's concept of causality and the dynamic characteristics of the series will be shown by simulations with exogenous shocks.

A considerable number of time series studies in recent years has concentrated on the investigation of the causal relationship between money and income (pioneered by Sims 1972) on the one hand and the causation between employment and the real wage on the other (Sargent 1978, Neftci 1978, Geary/Kennan 1982, Ashenfelter and Card 1982). In these fields of application, causality tests were also performed with Austrian data (Handler 1985, Neusser 1986, Winckler/Kunst 1986). In contrast, the direction of causation between exports and productivity -despite its important policy implications - has not been subjected to empirical tests of this sort up to now.

The present study on the relationship between exports and technical change uses the Wiener-Granger concept as a statistical test for causality; leaving aside the debate on the meaning of the test itself. Several authors (Zellner 1979, Leamer 1985) maintain that causality is a meta-concept which at best can be covered partly only by empirical methods. However, if the possibility of empirical causality testing is accepted, the Granger setup is almost inevitable, albeit still subject to more technical caveats.

The paper is organized as follows. In section 2 the theoretical link between exports and technical change as provided by different theories will be briefly discussed. Section 3 gives a review of Granger's concept of causality and describes the testdesign pursued. In section 4 the time series data are presented in univariate and mulitvariate autoregressive form and the results of various causality tests are shown. Furthermore, simulations investigating the dynamic relationship between the time series are performed in this section. Finally section 5 summarizes the findings and draws tentative policy implications.

2. Competing Causal Explanations

There are only few theoretical studies which examine the relationship between technical change and trade. The literature which integrates growth theory with international trade adresses the question whether trade increases the growth rate of output of an economy. The results of these models are inconclusive. The answer seems to depend on whether the country exports consumption goods and imports investment goods or the reverse. If the former is the case, increases in the growth rate of output as a result of trade can be shown. These models propose a causal link which runs from trade to the growth rate of output, but they do not deal explicitly with the effects of trade on technical change and productivity (for a discussion of this literature see Findlay 1984).

The export-led growth models to be found in the literature on applied growth theory, in turn, stress the hypothesis that exports are a key factor in promoting economic growth. The positive contribution of exports to growth is not meant in the obvious sense that exports increase aggregate demand and hence output. Several explanations for the causal link between exports and productivity were put forward (see Balassa 1978, Bhagwati and Srinivasan 1978, Caves 1971, Krueger 1980 and the debate in the 1960's in several issues of Kyklos among them Ball 1962, Massell 1964 and Emery 1967; and a more recent study of the World Bank 1982). First, exports are seen to concentrate investment in the most efficient sectors of the economy - those in which the country enjoys a comparative advantage. Stronger specialization in these sectors is seen to increase productivity. Second, higher export growth is viewed to allow the country to gain from economies of scale as the inclusion of the international market to the domestic market is seen to permit larger scale operations than does the domestic market alone. Third, stronger exposure to international competition by higher exports is considered to increase the pressure on the export industries to keep costs low and provide incentives for the introduction of technological change which improves productivity.

Beckerman's export-led growth model suggests even a virtuous circle in productivity growth induced by an initial export stimulus (Beckerman 1965). The causal explanation for this is as follows. The growth of export demand in a small open economy is considered to be an important determinant of investment. Furthermore, it is argued, that the smaller the domestic market, the greater the importance of external demand in enabling economies to reap economies of scale in production thereby making enterprises internationally competitive. Higher export and output growth leads to higher productivity growth as Verdoorn's law is considered to be valid. Besides the Verdoorn relation giving rise to higher productivity growth, the higher export earnings tend to stimulate new investment embodying best-practice techniques which, in turn, leads to an increase in the growth rate of factor inputs per unit of output. The resulting higher productivity growth contributes to a lower rate of growth of wage costs per unit of output assuming wages not to rise in line with productivity. The lower rate of increase in unit labour costs, in turn, leads to a lower rate of domestic price increase which results in a further acceleration in the rate of growth of exports as export growth is taken to be a function of the difference in the rate of growth of domestic and foreign prices expressed in the same currency. This way the export induced virtuous circle in productivity growth becomes complete. Technological improvements are seen to be translated in an increase in price competitiveness. Thus besides a causal influence of exports on productivity, the model predicts also a causal influence of price competitiveness on exports.

Compared to the models described above, the technology theories of international trade (technology gap and product cycle theories) propose a causal link which runs from technical change to trade rather than vice versa (see Vernon 1966, Hirsch 1967, Posner 1961, Krugman 1979, 1982). Competitive performance in export markets is attributed by these models to market power achieved through innovation.

As new products and processes are being developed, the country in which these innovations occur will for a time enjoy a technological advantage over its trading partners in these products. This will lead the innovating country to export these goods even though it has no comparative advantage in terms of factor intensities and endowments. The new product will go through a cycle of systematic changes in technology and its producer will be faced with a changing competitive environment. At first, the new product requires large amounts of skilled labour in its production and provides the innovating firm with a monopoly position on the market as potential competitors face a technological barrier to entry. As larger quantities are demanded, however, more routinized and capital intensive production techniques become available and price competition starts with entry barriers being overcome by other firms. Thus, the model predicts not only a causal influence of technology on exports but attributes also minor influences of price competitiveness on the export performance in the early phase of the product cycle. The model suggests, therefore, that the higher the share of newer products on total export volume of a country the less important are relative prices for export growth.

As the technology-oriented theories of trade emphasize the differences across countries in technologies as the source of international trade (especially Posner's 1961 version), they can be viewed as a generalization of the Ricardian model in a dynamic context. The Ricardian model attributes comparative advantage between countries unchanged over time entirely to differences in labour requirements of production, while the technolgy theories of trade consider innovations constantly occuring in the originally innovating country, with the new technology steadily diffusing to the rest of the world; technology diffusion accompanied by shifts in comparative advantage between countries.

Both the Ricardian model as well as the technology theories have been subject of a considerable number of empirical tests. While several specific tests have been performed, the most direct test of the Ricardian model has been a log linear regression of the ratio of U.S. to U.K. exports on the ratio of U.S. to U.K. labour productivities, showing a positive and significant correlation between these two variables (see Stern 1962, Balassa 1963 and Bhagwati 1964). Recently, this has been challenged by Falvey 1981 as a test of the Ricardian model, as other trade models are likely to predict the same relationship. Empirical tests of the technology explanation of trade, in turn, correlated U.S. export performance across industries with various measures of technology-related variables such as R&D (Keesing 1967, Gruber, Mehta and Vernon 1967, Lowinger 1975 and Stern and Maskus 1981), human capital or labour skill ratios (Hirsch 1975 in a multicountry framework, Branson and Monoyios 1977) and patents issued (Soete 1981; for another test of the product cycle model using rates of price decline over time as an indicator of newness see Bowen 1981). Whatever its source, the importance of technology as a determinant of exports finds strong support by these studies suggesting that technical change plays a role in international trade.

The analysis which follows is not a further empirical test on either the export-led growth model or the technology theories of trade. While the empirical studies reported assume a specific causal relationship between the variables without testing it, the present paper performes a statistical test on the causal structure without claiming to test the theories. The results indicate whether the data contradict or are compatible with the causal hypotheses implied by the theories presented in this section.

3. Testing Granger Causality

3.1 Causality Tests

Granger (1969) defined his statistical concept of causality as follows. Given a universe including the two series (X_t) and (Y_t), X is said to cause Y if the forecast for Y_t from the history of the universe excluding X can be improved by taking the history of X into account. The optimal way to make this definition operational is still unknown, although recent simulation studies seem to favor slightly modifications of Granger's original test procedure over its competitors (e.g. the method of Sims 1972).

In this paper two different testing methods are pursued. Both approaches are based on the original Granger procedure and are applied to universes consisting of three series. Let (X_t, Y_t, Z_t) be a three-dimensional (covariance-) stationary process. Provided a finite trivariate autoregressive (AR) representation exists

$$\Phi(L)\begin{pmatrix} X_t \\ Y_t \\ Z_t \end{pmatrix} = \begin{pmatrix} \Phi_{11}(L) & \Phi_{12}(L) & \Phi_{13}(L) \\ \Phi_{21}(L) & \Phi_{22}(L) & \Phi_{23}(L) \\ \Phi_{31}(L) & \Phi_{32}(L) & \Phi_{33}(L) \end{pmatrix} \begin{pmatrix} X_t \\ Y_t \\ Z_t \end{pmatrix} + \begin{pmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \end{pmatrix} \qquad (3.1)$$

$(e_{1t}, e_{2t}, e_{3t})'$ jointly white noise

Granger causality may be investigated by testing the off-diagonal elements of $\Phi(L)$ to be different from zero polynomials. For instance, "Y causes X" may be tested by the Φ_{12} polynomial, "Z causes X" by Φ_{13} and so on. Tests for polynomial zeros may be carried out by testing the joint significance of the corresponding lag coefficients, that is, by likelihood-ratio tests or operational approximations such as the usual F-statistics of OLS regression.

The two testing methods differ with regard to the specification of the trivariate AR models (3.1). Since causal directions often rely on just a few lags of the source variable, the lag structure imposed a-priori on the polynomials Φ_{ij} is important. If those lags are ignored in the model the test procedure necessarily fails to detect causality. On the other hand, excluding lags in the Φ_{ii} might shift explaining power to the off-diagonal polynomials thereby generating spurious causality. Due to the finiteness of the sample at least some restrictions have to be specified. For the diagonal elements, the optimal univariate autoregressive models chosen by the Akaike Information Criterion (AIC) offer themselves as a starting point.[1)] In the first testing approach the maximal lag for the off-diagonals was set to four in accordance with the quarterly data and with the requirements concerning the degrees of freedom. In this approach, henceforth denoted UVAR (for unrestricted vector autoregressive), no further restrictions on the lag struture were imposed.

The UVAR test procedure involves several problems. Significant lags in the off-diagonal polynomials might be ignored, so that existing causal influences are not detected. Especially, economic theory often suggests longer-run influences that are not captured by a four-lags model. Generalizations of criteria like AIC to multivariate models are at hand but are not widely accepted. The inflation of insignificant parameters, near-multicollinearity and loss of degrees of freedom in models like (3.1) suggest more sensitive modelling, either in a Bayesian fashion or by zero restrictions taken from the data. The latter way leads to so-called subset models.

As the second test procedure such subset models were specified in the following way. Variable (subset) selection started from a maximal model obtained by setting the maximal lag of the Φ_{ii} to the respective AIC and to the off-diagonals to 8. Although Haggan & Oyetunji (1984) see no difficulties with regard to the computer time involved with computing the AIC (or some other criteria) of all possible subset models in a univariate framework, we faced such problems and rather used naive selection and elimination based on the t-statistics of single parameters and the r^2c of the overall equation. The resulting model, which is unlikely to be too faraway from the best out of approximately 2^{60} (the total number of subsets),will be denoted as SMAR (for subset model AR). Although the imposition of zero restrictions is sometimes criticized, there is now growing empirical evidence for

1) AIC was defined by Akaike (1973) to be the sum of T times the lagged residual variance plus twice the number of parameters contained in the model. Additional parameters reduce the first terms and increase the second, eventually producing a minimum which is then used (T denotes the sample size).

subset models outperforming unrestricted vector-AR (Haggan & Oyetunji 1984, Kunst & Neusser 1986).

The power of the procedures relies on the assumption of correctly specified AR models. An additional moving-average (MA) part causes problems (see Kang 1981), but the most important issues in practice are non-stationarity of the data-generating process and correct treatment of the lag structure. Non-stationarity features like common trends or seasonality, which are observed frequently with economic data, may be a source of spurious causality. Removal of non-stationarity has been done mostly by ad-hoc procedures like first or fourth differences or the controversial Sims filter (Sims 1972) or by adding dummy variables for seasonal constants and linear trend. Some care with these approaches is necessary, as unjustified differencing may destroy causal relationships by deletion of parts of the power spectra, especially low frequences. However, in the case of our data, trends were clearly visible, and thus first differences were taken before beginning with the definite causality procedure. By looking at the power spectra a certain amount of seasonal cycles can be found which is reflected in the reported time series models. The correct treatment of seasonal components in causality tests is a difficult task, especially since theoretical results are not at hand. Simple differencing is likely to destroy causal patterns by deleting frequencies, whereas the effects of sophisticated seasonal adjustment algorithms (e.g. X-11) are unknown. Therefore, no corrections of the data were undertaken in this direction.

3.2 Instantaneous Causality

Granger (1969) added to this basic definition of causality another important concept. If the contemporary value X_t provides information for predicting Y_t additionally to the history of the whole "universe" which includes all past values of (X_t) and $Y_t)$, X is said to cause Y instantaneously. Sims (1972) proved that source and effect cannot be separated in this case and Pierce & Haugh (1977) presented a test procedure for this phenomenon which avoids the identification problems of the original Granger approach. If the vector AR model for the causality test is specified and estimated, instantaneous causality may be tested by the correlation matrix of the residuals from the vector AR model. High correlations indicate high instantaneous causality.

Usually, instantaneous causality is to be taken as an indicator of flaws in the model rather than of an additional causal structure. Since the time interval between two data points is non-zero (three months in the present case) all quicker effects are captured by the instantaneous causality table.

3.3 Simulations with Exogenous Shocks

Economic theory provides information not only on the direction and intensity of the relationship between variables but also on the shape of the dynamic interaction, that is the phenomenon that can be reduced to the sign of the coefficient in a non-dynamic model. Looking at the sum of coefficients or at the lag structure of corresponding lag polynomials represents an incomplete way to investigate the dynamic structure as the feedback loops running between the completely endogenous variables are ignored. Sims (1980) suggested simulations on the basis of changing just one residual at one time point keeping all the remaining residuals at zero and the corresponding variables at the stationary equilibrium.

In the SMAR model, changing one residual at a time cannot be done while the remaining residuals are kept at zero since the residuals are interrelated by instantaneous causality effects. Thus, before the simulation can be put into practice, the model must be triangularized in the way described by Sims (1980) to generate an equivalent description of SMAR with independent errors but with contemporary values of other variables appearing in the equations. Additionally, the stationary equilibrium has to be calculated. In a homogenous model, the stationary equilibrium means that all variables are zero. However, if constants are retained in the equations a linear difference equation scheme has to be solved in order to obtain the equilibrium values.

4. Time Series Representation of Exports, Productivity and the Terms of Trade

4.1 Data

In order to compare the causal predicitons implied by the models described in section 2 with the Austrian facts, data for exports, price competitiveness and for technological change were required. We have used exports of manufactured goods as the export variable and the terms of trade (export unit values divided by import unit values for manufactured goods) in home currency as a measure for price competitiveness. As the time series analysis required quarterly data, a serious problem we faced was to find an adequate measure for technical innovation. Since neither R & D data nor other possible candidates for a measure of technical change are available at this level of time aggregation, we decided to use labour productivity of manufacturing as a proxy for technical change. Labour productivity can be seen as an adequate reflection of technical change only in case of constant returns to scale and a constant capital coefficient. While the latter approximately holds for Austria, the former cannot be assumed. The development of labour productivity reflects, therefore, technical change as well as some sort of economies of scale. Alternatively, we performed the whole exercise with investment data for the entire economy, as investment for the manufacturing sector was not available in quarterly disaggregation. Thus, the results with this variable should be interpreted with caution, as the investment data include investment in construction and public investment as well (for the results see Appendix).

From the theoretical point of view it would have been suggestive to include a world trade variable in the time series study in order to control for export growth which results neither from technology nor from price competitiveness but from growth in world trade; an extension which could not be realized for the lack of corresponding data on a quarterly basis.

4.2 Univariate Autoregressive Representation

In order to get a first impression of the stochastic feature of the time series, Table 1 provides the univariate autoregresssive representation of the Austrian quarterly time series (detrended by first differences) on exports (XG), labour productivity

(PROD), the terms of trade (PTR) and investment (IFE) as it was obtained by the AIC criterion (see footnote 1 for an explanation of this criterion). As can be readily seen, labour productivity and investment may be described by high order processes, AR 6 and AR 4 respectively. Exports and the terms of trade show remarkable similarities with each series following an AR 3 process. The reduction in variance indicates that productivity and investment can be reasonably well explained by their own history, while this is not so for exports and the terms of trade.

Table 1

UNIVARIATE AUTOREGRESSIVE REPRESENTATIONS[(a)]

Regressors	Dependent Variable[(b)] (t-values in parentheses)			
	XG	PROD	PTR	IFE
AR 1	0,46 (4,4)	0,52 (4,8)	0,56 (5,3)	0,71 (6,7)
AR 2	-0,04 (-0,4)	0,02 (0,1)	0,36 (3,1)	0,47 (3,8)
AR 3	0,32 (3,1)	0,31 (2,7)	0,27 (2,6)	0,41 (3,4)
AR 4	-	-0,37 (-3,2)	-	-0,24 (-2,3)
AR 5	-	-0,04 (-0,3)	-	-
AR 6	-	0,18 (1,6)	-	-
reduction of variance	0,51	0,908	0,265	0,686

Note: (a) all regressions cover 1964.2-1985.1; for productivity: 1964.2-1984.4

(b) the series (exports XG, productivity PROD, terms of trade PTR, investment IFE) were detrended by first differences.

4.3 Unresticted Vector Autoregression (UVAR) and Causality

In Table 2 the three variable vector autoregression fitted by least squares over the sample period indicated is reported using the AIC criterion to determine the lag structure for the diagonal elements and including four lags for the off-diagonals (for details to the UVAR test procedure see section 3.1).

The first column shows that there is a weak indication of effects of lagged prductivity and no indication of effects of lagged price competitiveness on exports. Only the coefficient of the three quarters lagged productivity is significant at the 5 % level, while the remaining lagged productivity and price terms are not. This result is also supported by the formal causality test of each of these hypotheses contained in Table 3. The F-ratios and prob-values to test whether exports are Granger-caused by productivity and/or price competitiveness indicate that productivity causes exports while the causation of relative prices on exports is a great deal short of statistical significance.

Continuing with the second column of Table 2, current productivity is significantly influenced by exports at one and three quarter and four quarter lags, respectively. In contrast to what would have been expected by the export-led growth model, however, the overall impact of exports on productivity as obtained by the sum of the coefficients, seems to be negative. The evidence that the terms of trade influences productivity is weak as only price competitiveness at one quarter lag is statistically significant at the 10 % level. The causality tests reported in Table 3 come to similar conclusions. The F-statistic for the test of causality suggests a strong causal link from exports to productivity, while causality from the terms of trade to productivity is not significant at conventional levels.

The third column of Table 2 provides estimates of the coefficients of lagged exports and productivity in the regression for price competitiveness. While the impact of lagged exports is weak, there is no effect of lagged productivity on the terms of trade. This is again confirmed by the causality test in Table 3.

Table 2

VECTOR AUTOREGRESSIVE REPRESENTATION OF EXPORTS, PRODUCTIVITY AND TERMS OF TRADE (UVAR-MODEL)[a]

Regressors	Dependent Variables (t-values in parentheses) XG	PROD	PTR
XG_{-1}	-0,26 * (1,44)	0,63 ** (3,19)	-0,03 (0,11)
XG_{-2}	0,07 (0,33)	0,18 (0,72)	-0,35 * (1,34)
XG_{-3}	-0,37 ** (2,16)	-0,63 ** (2,64)	-0,39 * (1,62)
XG_{-4}	-	-0,61 ** (2,92)	0,31 * (1,3)
$PROD_{-1}$	-0,17 * (1,16)	-0,62)** (3,94)	0,19 (1,01)
$PROD_{-2}$	0,13 (0,91)	0,02 (0,08)	0,09 (0,51)
$PROD_{-3}$	0,24 ** (2,25)	0,04 (0,24)	0,18 (1,1)
$PROD_{-4}$	-0,003 (0,03)	0,41 ** (2,86)	0,29 * (1,78)
$PROD_{-5}$	-	-0,03 (0,26)	-
$PROD_{-6}$	-	0,11 (0,8)	-
PTR_{-1}	0,03 (0,29)	0,18 * (1,62)	-0,4 ** (3,21)
PTR_{-2}	-0,09 (0,85)	0,11 (0,92)	-0,3 ** (2,3)
PTR_{-3}	0,01 (0,09)	0,08 (0,67)	-0,18 * (1,46)
PTR_{-4}	0,07 (0,77)	-0,08 (0,78)	-
CONST	0,96 ** (2,96)	1,35 ** (3,43)	-0,91 ** (2.11)
R^2	0,64	0,97	0,49
SE	1,74034	1,82693	2,29968

Note: (a) all regressions cover 1965.2-1985.1; for productivity 1965.2-1984.4.

**, * indicate 5 and 10 percent level of significance, respectively.

Table 3

CAUSALITY TESTS FOR EXPORTS, TERMS OF TRADE AND PRODUCTIVITY (UVAR-MODEL)[a]

Test for causality of	by	Test Statistic[b]	Prob value[c]
XG	PROD	2,8	3,26
	PTR	0,76	55,47
PTR	PROD	0,81	52,18
	XG	1,78	14,34
PROD	PTR	1,22	31,02
	XG	6,3	0,02

Note: (a) All regressions cover 1965.2-1985.1; for productivity 1965.2-1984.4.

(b) The causality test statistic is an F-ratio for the null-hypothesis that the coefficients of four lagged values of each of the variables in the second column are jointly equal to zero. The number of lagged values of the dependent variable included in the regression equals that obtained by the AIC criterion (shown in Table 1).

(c) Probability of obtaining an F-ratio at least as large as the test statistic under the null-hypothesis. A prob value smaller than 5 indicates rejection of the null hypothesis at the 5 percent significance level.

4.4 Subset Model Autoregression (SMAR) and Causality

The results of the UVAR test procedure left us somewhat unsatisfied because of the following reasons. First, the relationship between exports and technical change might not be one of the short term but one of medium term. The introduction of technical change might not only lead to an immediate acceleration in export growth but also increase exports in the medium term. Similarly, the export stimulus might need some time to work through the system until it boosts technical change. The negative impact of exports on productivity shown in column 2 of Table 2 might have been caused by a too short a lag structure selected. Second, several of the included four lags in each variable were insignificant at the 10 % level suggesting that a different lag structure might be statistically more adequate.

These objections motivated us to use the SMAR test procedure as an alternative which differs from the UVAR approach by restricting statistically insignificant lags to zero and by allowing up to eight lags for the off diagonal elements in order to account for medium term influences (for details on the methodology see section 3.1).

A first look at Table 4 which reports the results of the subset model vector autoregression for exports (XG), producitivity (PROD), and price competitiveness (PTR) fitted by least squares in fact reveals that medium term effects are at work. Compared to the UVAR procedure, however, the overall picture seems not to be changed substantially. The first column of Table 4 and the causality tests in Table 5 indicate that the positive causal link from productivity to exports has become much stronger than in the UVAR approach (the F-ratio increased from 2.8 in Table 3 to 6.7 in Table 5). The hypothesis that relative prices Granger-cause exports even became statistically significant at the 8 % level, while it was far from being significant in the UVAR model (compare Table 3 and 5). However, the sign of the causal influence is ambiguous when the sum of the lagged price coefficients is calculated.

To sum up, both test procedures suggest that the Austrian data are compatible with the causal structure implied by the technology theories of international trade.

While the test that technical change as measured by labour productivity Granger-cause exports finds strong statistical support, the evidence that price competitiveness causes exports is weak. This is in accordance with the product cycle model as well as with estimates of Austrian export price elasticities which are of small absolute size and often are statistically not significant at conventional levels (see Marin 1986a for estimates of export price elasticities on a sectoral level and Breuss 1983 for a review of estimates of Austrian export price elasticities).

From column 2 of Table 4 and from the causalitiy test in Table 5 emerges that the extension of the lag structure to allow for medium term influences has somewhat strenghtened the negative causal influence of exports on productivity. As the signs of the estimated coefficients of lagged exports in column 2 show, however, an export stimulus leads at first to an acceleration in productivity growth which turns to a deceleration in the medium term. This might reflect the productivity increasing impact of higher demand on capacity utilization and on economies of scale in the short term and the productivity decelerating effect of the lack of competitive pressures on the export industries when export demand is high in the medium term. It seems, therefore, that in the short run the capacity and scale effect dominate productivity growth, while in the medium term the lack of the rationalization effect dominates all possible other influences on productivity[2)].

This interpretation seems to be supported by an inspection of the coefficient estimates of lagged price competitiveness in column 2 of Table 4. The influence of lagged price competitiveness on productivity appears to have exactly the opposite pattern than those of lagged exports. While an increase in price competitiveness (a deterioration in the terms of trade) through e.g. a depreciation of the exchange rate increases productivity in the short term (through the capacity and scale effect of higher exports), losses in price competitiveness through e.g. a revaluation of the exchange rate accelerate productivity growth in the medium term (through the rationalization effect of stronger competitive pressures) with the latter effect dominating the process (see also next section for the dynamic characteristics of the time series).

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2) For the scale and rationalization effect which play an important role in the evaluation of effects of protectionism or other industrial policy measures see Helpman/Krugman 1985.

Table 4

VECTOR AUTOREGRESSIVE REPRESENTATION OF EXPORTS, PRODUCTIVITY AND TERMS OF TRADE (SMAR-MODEL) (a)

Regressors	Dependent Variables (t-values in parentheses)		
	XG	PROD	PTR
XG_{-1}	-0,41 ** (3,46)	0,45 ** (3,29)	-
XG_{-2}	-0,09 (0,64)	-	-0,38 ** (2,27)
XG_{-3}	-0,34 ** (2,36)	-0,76 ** (4,29)	-0,42 ** (2,01)
XG_{-4}	-	-0,61 ** (3,23)	0,35 * (1,7)
XG_{-6}	-	-0,21 * (1,1)	-0,15 (0,65)
XG_{-7}	-	-0,63 ** (3,26)	0,11 (0,46)
XG_{-8}	-	-0,43 ** (2,5)	-
$PROD_{-1}$	-	-0,71 ** (5,95)	0,11 (0,87)
$PROD_{-2}$	0,14 * (1,28)	-	-
$PROD_{-3}$	0,33 ** (3,33)	-0,08 (0,57)	-
$PROD_{-4}$	-	0,17 * (1,3)	0,23 * (1,56)
$PROD_{-5}$	-	-	-0,35 ** (2,3)
$PROD_{-6}$	0,07 (0,7)	0,15 * (1,24)	-0,39 ** (2,42)
$PROD_{-7}$	-	-	-0,41 ** (2,58)
$PROD_{-8}$	0,23 ** (3,08)	-	-0,46 ** (2,78)
PTR_{-1}	-	-	-0,5 ** (4,25)
PTR_{-2}	-0,14 ** (1,82)	-0,09 (1,01)	-0,38 ** (2,85)
PTR_{-3}	-	-	-0,31 ** (2,48)
PTR_{-5}	0,13 * (1,71)	0,15 * (1,71)	-
PTR_{-6}	-	0,19 ** (2,03)	-
PTR_{-7}	0,1 * (1,26)	0,12 * (1,3)	-
CONST	0,71 ** (2,27)	2,86 ** (6,43)	0,65 * (1,17)
R^2	0,69	0,97	0,63
SE	1,65516	1,68938	2,07132

Note: (a) all regressions cover 1966.2-1985.1; for productivity: 1966.2-1984.4

**,* indicate 5 and 10 percent level of significance, respectively.

Table 5

CAUSALITY TESTS FOR EXPORTS, TERMS OF TRADE AND PRODUCTIVITY (SMAR-MODEL)[a]

Test for causality of	by	Test Statistic[b]	Prob value[c]
XG	PROD	6,73	0,01
	PTR	2,32	8,4
PTR	PROD	3,27	0,75
	XG	2,15	7,11
PROD	PTR	1,68	16,69
	XG	6,86	0,0

Note: (a) all regressions cover 1965.2-1985.1; for productivity 1965.2-1984.4.

(b) The causality test statistic is an F-ratio for the null hypothesis that the lagged coefficients (as reported in Table 4) of each of the variables are jointly equal to zero. For details see text on the SMAR-Model in section 3.1.

(c) as note (c) in Table 3.

Table 6

CORRELATION MATRIX OF INNOVATIONS (SMAR-MODEL)[a]

	XG	PROD	PTR
XG	1,0000		
PROD	0,4494	1,0000	
PTR	-0,2468	0,2804	1,0000

Note: (a) Residuals obtained from estimated equations reported in Table 4.

Although the causal influence of price competitiveness on productivity is statistically weak (it is significant at the 17 % level only, see Table 5), other studies suggest that such a rationalization effect is at work (see Marin 1985, 1986b).

It seems, therefore, that the present time series study does not confirm the causal predictions implied by the export-led growth model in the medium term. Neither an export stimulus, nor increases in price competitiveness through e.g. a depreciation of the exchange rate seem capable to increase productivity growth in the medium term as is suggested by the model.

Compared to the UVAR approach, the test whether productivity and/or exports Granger-cause price competitiveness has in the SMAR procedure much stronger statistical support (compare the F-ratios and prob-values in Table 3 and 5). As the sum of the coefficients seems to suggest, increases in productivity as well as in exports lead to improvements in price competitiveness; the latter through lower unit costs obtained by better export induced capacity utilization.

Finally, in Table 6 estimates of the correlations among the innovations (residuals) from the regression reported in Table 4 are provided, which can be interpreted as instantaneous causality (see section 3.2 for definition). The strongest correlation exists between innovations in exports and productivity. The unpredicted parts of these two series move in the same direction, just as the level of both series move in the same direction over the business cycle. As it was shown before, exports and productivity are closely linked; a linkage which also extends to the surprises of these series. The other two correlations in Table 6, those between price competitiveness and exports on the one hand and productivity and price competitiveness on the other, are of much smaller but still substantial size suggesting that linkages between these variables are also at work in the unpredicted parts of these series.

4.5 Dynamic Interaction

Section 3.2 gave a rationale why the calculation of the sum of the coefficients is an incomplete way for determining the sign of the causal linkages investigated in the preceding section. As the sign of the influence is important for discriminating between the causal hypotheses implied by the theories and the results of the summation method often were ambiguous, we decided to use simulations to get a clearer picture of the dynamic interaction between the time series. The equilibrium values obtained by the solution of the linear difference equations were .8077, .7099, and -.3354 for PROD, XG and PTR respectively which were used as the stationary equilibrium for the simulations, (for details on the methodology see section 3.3). In Figures 1 to 3 the effects of a residual shock of the size of one standard deviation with respect to each equation of Table 4 are reported.

It appears that a productivity shock leads to an acceleration of exports in the medium term which is reinforced by a productivity induced improvement in price competitiveness (Figure 1). Contrary to this, an export shock leads to a decline in productivity with a deterioration in price competitiveness following it (Figure 2). A terms of trade shock (loss in price competitiveness), in turn, seems not to have much impact neither on exports nor on productivity (Figure 3). Thus, the results of the previous sections seem to be confirmed by the simulations. Productivity causes exports positively as is suggested by the technology theories of trade, while exports cause productivity negatively which contradicts the causal hypotheses implied by the export-led growth model.

Figure 1

PRODUCTIVITY SHOCK

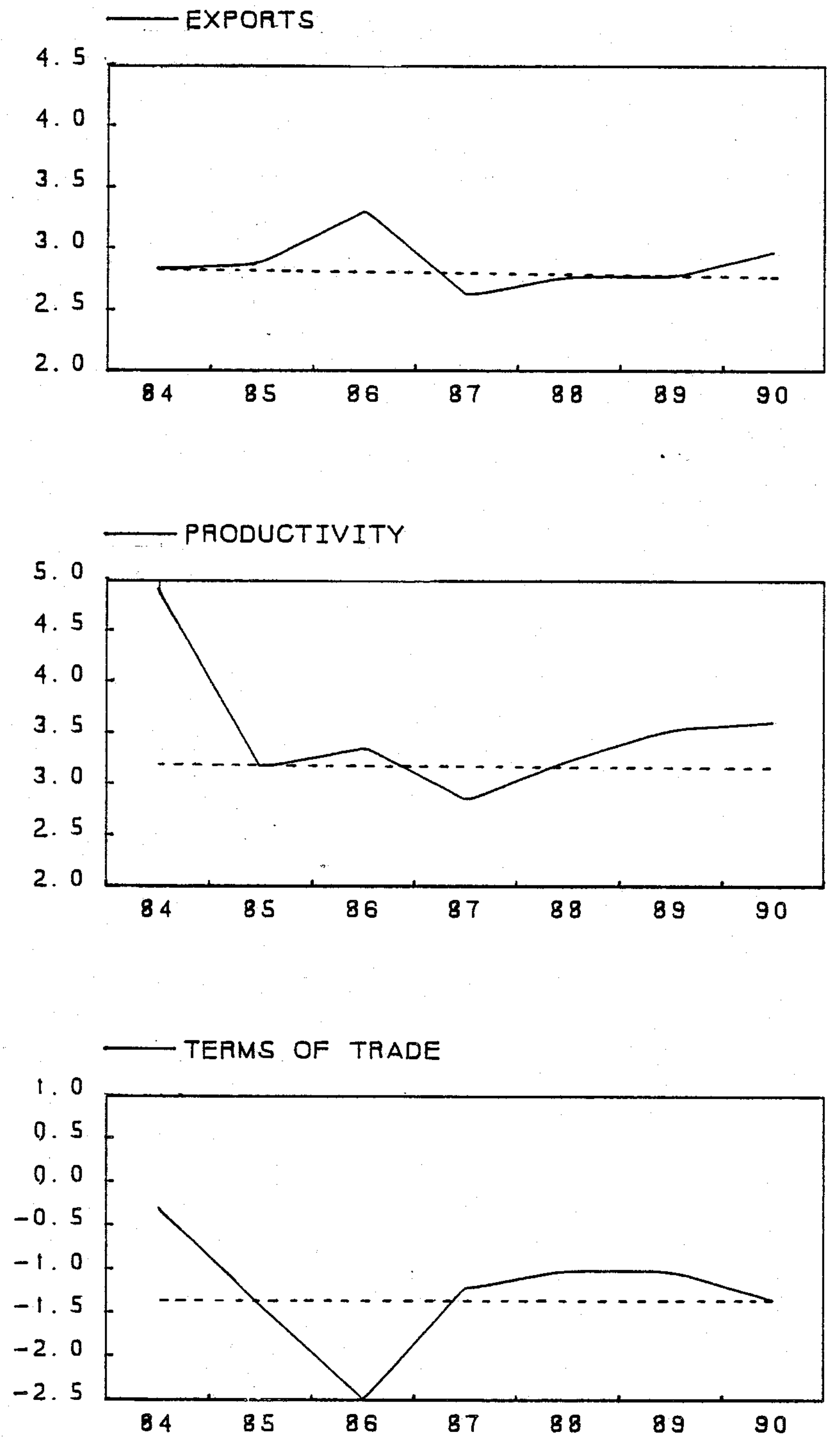


Figure 2

EXPORT SHOCK

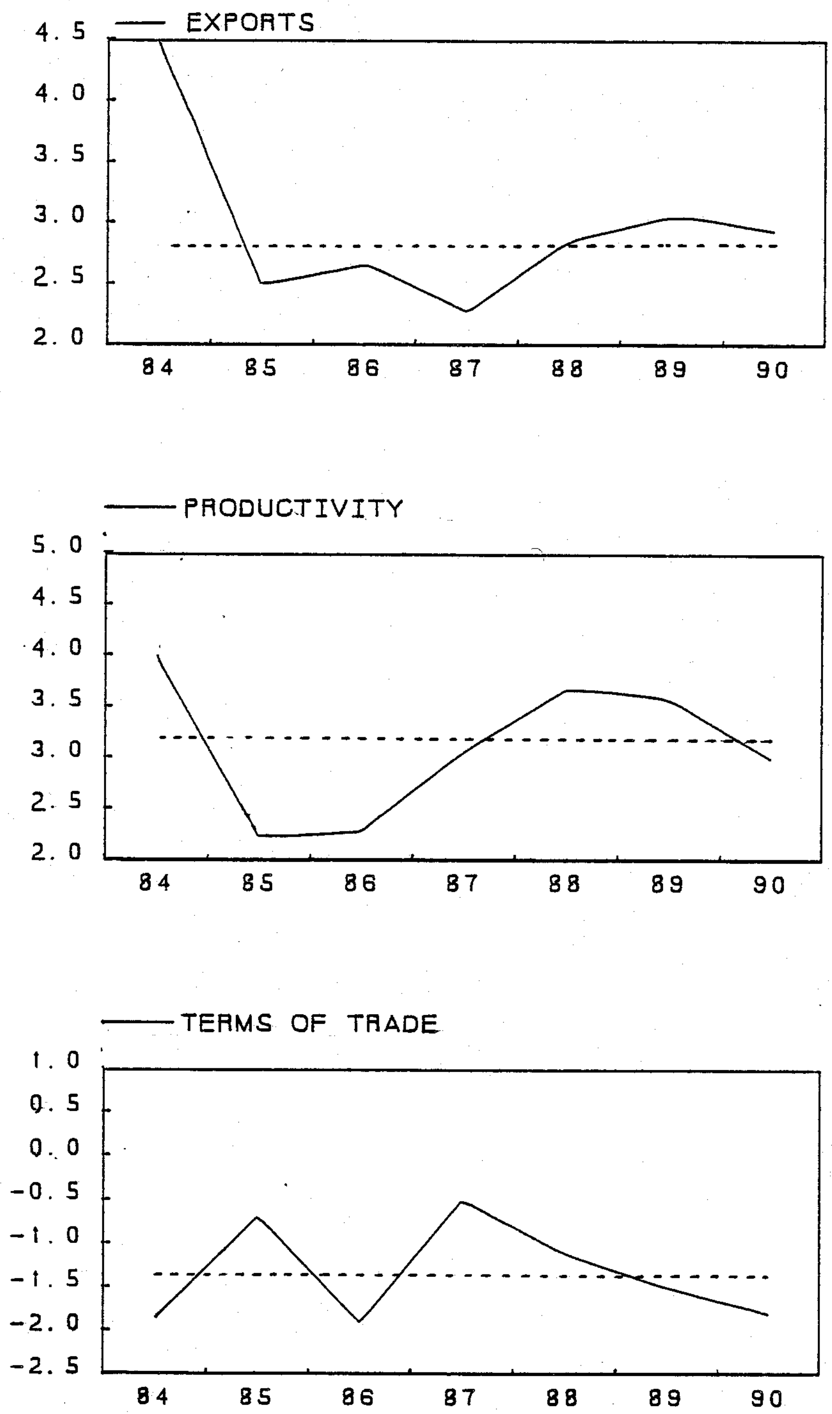
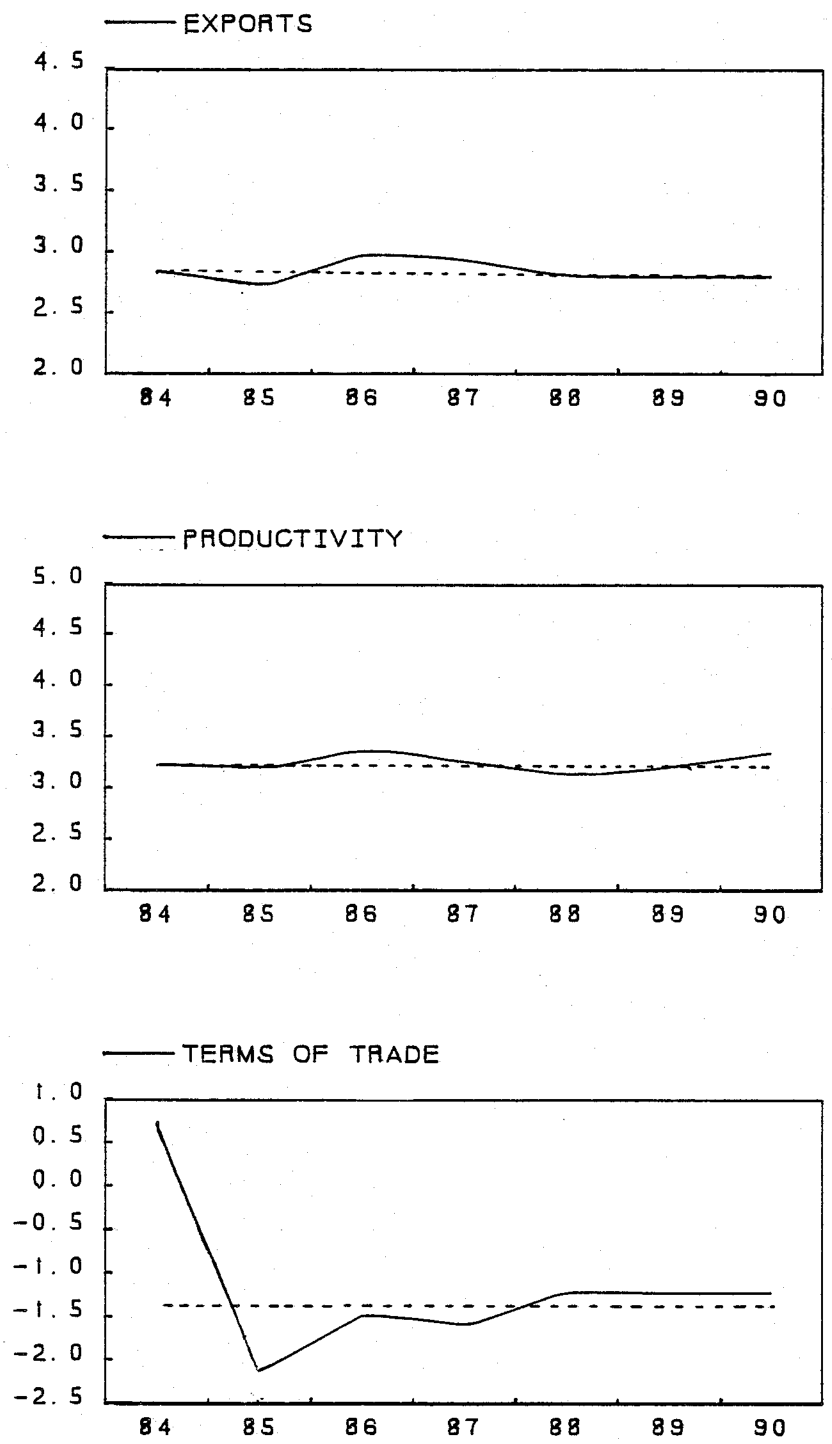


Figure 3

TERMS OF TRADE SHOCK



5. Conclusions

In this paper we have investigated the relationship between technical change and exports using time series analysis. The regressions reported in Tables 1-6 provide the data and the causality tests that challenge the causal hypothesis implied by the export-led growth model. The causality analysis indicate a negative causal link from exports to productivity, while the estimated positive causal link from technical change to exports seem to be consistent with the causal hypothesis of the technology theories of international trade. Additionally, the found weak causal linkage from price competitiveness to exports seem to be in accordance with the product cycle model which suggests that price competition is the less important the newer the product. This is also compatible with empirical estimates of Austrian export price elasticities which are of small absolute size and often were statistically insignificant at conventional levels.

The estimated negative causal link from exports to productivity on the one hand and the weak although observable positive causal influence of a loss in price competitiveness (through e.g. a revaluation of the exchange rate) on productivity on the other suggest that devaluations of the exchange rate seem not to be capable of boosting productivity and technical change in the medium term as is suggested by the virtuous circle argument of the export-led growth model.

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Appendix

Time Series Representation of Exports, Investment and Terms of Trade

Table 7

VECTOR AUTOREGRESSIVE REPRESENTATION OF EXPORTS, INVESTMENT AND TERMS OF TRADE (UVAR-MODEL)[a].

Regressors	Dependent Variables (t-values in parentheses) XG	IFE	PTR
XG_{-1}	-0,47 (3,23)	0,01 (0,07)	0,3 (1,58)
XG_{-2}	0,12 (0,7)	-0,01 (0,11)	-0,19 (0,92)
XG_{-3}	-0,16 (1,07)	-0,04 (0,28)	-0,42 (2,01)
XG_{-4}	-	0,14 (1,04)	0,38 (1,81)
IFE_{-1}	-0,2 (1,2)	-0,68 (5,08)	-0,06 (0,29)
IFE_{-2}	-0,32 (1,67)	-0,43 (2,77)	0,02 (0,07)
IFE_{-3}	-0,39 (2,05)	-0,33 (2,12)	0,17 (0,71)
IFE_{-4}	-0,17 (1,13)	0,17 (1,19)	0,21 (0,96)
PTR_{-1}	-0,13 (1,48)	-0,02 (0,28)	-0,31 (2,62)
PTR_{-2}	-0,17 (1,77)	-0,11 (1,41)	-0,25 (2,19)
PTR_{-3}	0,002 (0,02)	-0,1 (1,31)	-0,17 (1,52)
PTR_{-4}	0,11 (1,21)	0,06 (0,76)	-
CONST	1,19 (4,15)	0,21 (0,84)	-0,63 (1,56)
R^2	0,61	0,73	0,48
SE	1,81967	1,45387	2,32661

Note: (a) all regressions cover 1965.2-1985.1.

Table 8

CAUSALITY TESTS FOR EXPORTS, TERMS OF TRADE AND INVESTMENT (UVAR-MODEL)[a]

Test for causality of	by	Test Statistic[b]	Prob-value[c]
XG	IFE	1,11	35,92
	PTR	1,87	12,56
PTR	IFE	0,402	80,65
	XG	3,42	1,32
IFE	PTR	1,38	24,99
	XG	0,47	75,89

Note: (a) all regressions cover 1965.2-1985.1.

(b) and (c) see notes to Table 3.

Table 9

VECTOR AUTOREGRESSIVE REPRESENTATION OF EXPORTS, INVESTMENT AND TERMS OF TRADE (SMAR-MODEL) [(a)]

Regressors	Dependent Variables (t-values in parentheses)		
	XG	IFE	PTR
XG_{-1}	-0,42 (3,16)	-	0,17 (1,12)
XG_{-2}	0,07 (0,46)	-	-
XG_{-3}	-0,25 (1,82)	-	-0,39 (1,98)
XG_{-4}	-	0,09 (0,79)	0,31 (1,39)
XG_{-5}	-	-	-0,18 (0,92)
XG_{-6}	-	-0,07 (0,62)	-0,68 (3,13)
XG_{-7}	-	-0,29 (2,49)	-0,31 (1,44)
IFE_{-1}	-0,14 (0,93)	-0,68 (6,07)	-
IFE_{-2}	-0,25 (1,39)	-0,41 (2,99)	-
IFE_{-3}	-0,17 (0,93)	-0,22 (1,67)	0,16 (0,81)
IFE_{-4}	-0,36 (2,45)	0,17 (1,3)	0,33 (1,59)
IFE_{-6}	-	-	0,14 (0,82)
IFE_{-7}	-0,24 (1,86)	-	-
IFE_{-8}	0,35 (2,63)	-	-0,35 (1,88)
PTR_{-1}	-0,12 (1,47)	-	-0,41 (3,26)
PTR_{-2}	-0,23 (3,08)	-0,1 (1,52)	-0,21 (1,76)
PTR_{-3}	-	-	-0,26 (2,16)
PTR_{-4}	-	0,06 (0,87)	-
PTR_{-5}	0,09 (1,23)	0,1 (1,48)	-
PTR_{-7}	0,14 (1,81)	-	-
PTR_{-8}	0,14 (1,74)	0,05 (0,79)	-
CONST	1,28 (4,6)	0,48 (2,2)	0,05 (0,1)
R^2	0,72	0,76	0,561
SE	1,62010	1,39854	2,22315

Note: (a) all regressions cover 1966.2-1985.1.

Table 10

CAUSALITY TESTS FOR EXPORTS, TERMS OF TRADE
AND INVESTMENT (SMAR-MODEL)[a]

Test for causality	by	Test Statistic[b]	Prob value[c]
XG	IFE	4,37	0,1
	PTR	3,27	1,11
PTR	IFE	1,44	23,09
	XG	3,38	0,6
IFE	PTR	1,61	18,16
	XG	2,84	4,48

Note: (a) all regressions cover 1966.2-1985.1

(b) The causality test statistic is an F-ratio for the null-hypothesis that the lagged coefficients (as reported in Table 9) of each of the variables are jointly equal to zero. For details see text on the SMAR-Model in section 3.1.

(c) as note (c) in Table 3.

Table 11

CORRELATION MATRIX OF INNOVATIONS
(SMAR-MODEL)[a]

	XG	IFE	PTR
XG	1,0000		
IFE	0,4385	1,0000	
PTR	-0,2381	-0,2513	1,0000

Note: (a) Residuals obtained from estimated equations reported in Table 9.