Nota: Determinants of Productivity Growth: Some International Evidence

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ABSTRACT

This paper presents some empirical evidence on the determinants of long-run growth in a number of OECD countries. An "analysis of variance" (ANOVA) model is estimated using OECD one-digit industry data on total factor productivity (TFP) in order to assess the relative importance of industry-specific, country-specific and international shocks (as well as interactions between industry and country effects). It is found that international factors are significant, although their contribution to TFP growth is small, and that interactions between country and industry effects were the main driving force in the eighties, when the importance of country (relative to industry) effects also increased. Over the whole sample period including the seventies and the eighties country - and industry-specific factors have the highest explanatory power.

KEY WORDS

analysis of variance (ANOVA), growth, international trade, globalisation

RESUMO

Este artigo apresenta alguma evidência empírica sobre os determinantes do crescimento a longo prazo para um grupo de países da OCDE. Um modelo de análise de variância (ANOVA) é estimado usando-se dados de produtividade total dos fatores (PTF) a fim de avaliar a importância relativa de efeitos específicos da indústria, efeitos específicos do país e de choques internacionais, assim como de interações entre efeitos da indústria e efeitos do país. Conclui-se que os fatores internacionais são significativos, embora sua contribuição para o crescimento da produtividade total dos fatores seja pequena, e que interações entre efeitos do país e da indústria foram a principal força propulsora nos anos 80, quando a importância dos efeitos específicos do país relativamente ao da indústria também cresceu. Quando se considera a amostra inteira (anos 70 e 80), fatores específicos do país e da indústria têm o maior poder explicativo.

PALAVRAS-CHAVE

análise de variância (ANOVA), crescimento, comércio internacional, globalização

JEL Classification

C23, F10, F43

INTRODUCTION

In the last few years a vast theoretical and empirical literature has emerged which considers long-run growth as an endogenous phenomenon (see, e.g., ROMER, 1990), and often links it to globalisation, i.e. the increasing economic integration of the world, and international trade patterns, in particular trade flows between the North and the South (see GROSSMAN & HELPMAN, 1991 and CURRIE *et al.,* 1998).

A strand of this literature focuses on the relationship between openness and growth. In particular, Grossman and Helpman (1991) identify three channels through which the former can influence the latter, i.e. idea flows, trade flows, and financial flows. They pay special attention to the relationship between international openness and the rate of innovation in the industrial economies. By contrast, the adoption of existing technologies appears to be more crucial in countries which lag behind the productivity leader.

Coe and Helpman (1995) present some evidence that idea flows play an important role, as "*foreign R&D has beneficial effects on domestic productivity, and that these are stronger the more open the economy is to foreign trade*." More specifically, they estimate the effects of domestic and foreign R&D capital stocks on total factor productivity (TFP) using pooled time series cross section data (their sample includes 21 OECD countries and covers the period 1971-1990) and pooled cointegration techniques. TFP is found to depend on both domestic and foreign R&D. Furthermore, in large countries the elasticity of TFP with respect to domestic R&D appears to be larger than with respect to foreign R&D, whilst the opposite is true in smaller countries, suggesting that a higher degree of openness is associated with bigger gains from R&D spillovers. Developing countries are also found to benefit from international trade, mainly through imports of machinery and equipment and the acquisition of useful knowledge (see COE, HELPMAN & HOFFMAISTER, 1997).

Some recent work (see SACHS & WARNER, 1995, and PROUDMAN, REDDING & BIANCHI, 1997) also suggests that open trade leads to convergent rates of growth, i.e. to higher growth rates in poorer (as opposed to richer) countries. A Schumpeterian interpretation would rationalise this finding in terms of technology transfers, R&D being seen as the engine of growth. An alternative explanation would be that openness is associated with higher levels of capital accumulation, as in the AK approach (see REDDING, 1997) for a survey of the theoretical and empirical literature on the links between openness and growth).

Of particular interest are the channels through which international trade can affect productivity growth. Cameron *et al.* (1998) discuss five of them, i.e. technology transfers, spillover of ideas, eliminating incentives for duplication in innovation, increasing the market size available to successful innovators, and increasing product market competition. Increased market size as a result of foreign trade in a model such as that of Romer (1990), leads to an increase in product variety and therefore in TFP (see FEENSTRA *et al.*, 1997 on how to measure product variety using foreign trade data).

Cameron, Proudman, and Redding (1997) link rates of growth of TFP in a country (in their case the UK) to the size of the productivity gap *vis-à-vis* the leading country (the US) and the degree of international openness, which is measured in five different ways (ratios of imports to output, exports to output, Inward and Outward FDI to output, trade-weighted R&D to physical capital). Single equation OLS and SUR techniques (allowing coefficients to vary across sectors), and panel data techniques are both used. There is mixed evidence that openness affects rates of TFP growth, although it clearly affects the rate of productivity convergence.

The empirics of growth and international trade are generally very challenging. Considerable difficulties are encountered when trying to carry out direct tests of alternative hypotheses suggested by economic theory, as often it is not clear what the empirical counterpart should be to some of the concepts used in the theoretical literature. This paper, therefore, takes an alternative approach, and provides some evidence on the relative impor-

tance of country-specific, industry-specific and international effects (as well as interactions between country and industry factors) which is based on the estimation of a simple statistical (rather than structural) model.

The layout of the paper is the following. Section 1 discusses productivity measurement issues, and sets out the econometric methodology. Section 2 presents the empirical results. Last Section offers some concluding remarks.

1. DATA ISSUES AND ECONOMETRIC METHODOLOGY

We used TFP series from the OECD International Sectoral Data Base (ISDB), which contains standardised annual data for 33 groups of industries in 15 OECD member countries. The industry classification used by the OECD broadly corresponds to that of the International Standard Industrial Classification (ISIC revision 2). In some cases, because of data unavailability, the OECD includes series whose definitions are based on the System of National Accounts (SNA), and hence system concordance matrices are constructed to obtain a consistent dataset. TFP is calculated as the difference between output growth and the weighted growth of factor inputs, namely labour and capital (for a general discussion on the main conceptual issues in measuring productivity, see BAUMOL *et al.*, 1989). A Cobb-Douglas (CD) specification is assumed for the production function. One limitation of this measure of productivity is that, because of lack of data, it is not based on hours actually worked, both for capital and labour. In order to obtain more reliable estimates of factor shares, total compensation is rescaled by the ratio of total employment to total employees so as to take into account self-employed when computing the weights. As the share of labour appears to be remarkably close to 70 percent in most countries and industries, TFP indices are computed by the OECD using a standardised weighting system as follows:

$$TFP=[VA/(ET^{w}GCS^{1-w}]/TFP_{0}$$

where TFP is the total factor productivity index, ET is total labour employed, GCS is the gross capital stock, VA is gross value added, w the

standardised labour share weights, and TFP_0 the 1990 value of TFP (for more details, see ISDB97).

The TFP series are constructed by the OECD using the expenditure-based purchasing power parity (PPP) approach. The alternative would be to take a "unit value ratio" (UVR) approach, theoretically more appealing, as in van Ark (1992) and Cameron *et al.* (1997). This method is preferable to the former, which is based on price measures which take account of imports and of trade and distribution margins, which should not be included for domestic output in manufacturing. Furthermore, PPP measures leave out a lot of price information on intermediate goods, which make up a significant share of manufacturing output. However, in order to construct UVRs one would have to use national data sources, such as the UK *Census of Production*, which are often not comparable, and hence both industry and country coverage would be limited (further details on data availability can be found in CAMERON, 1997).

Data limitations meant that only 11 OECD member countries could be included in the panel, namely Australia, Canada, Denmark, Finland, France, Great Britain, Japan, Norway, Sweden, United States and West Germany. For each of these countries we used TFP series for one-digit industries 1 to 8 according to the International Standard Industrial Classification (ISIC). These industries are: (1) Agriculture, hunting, forestry and fishing; (2) Mining and quarrying; (3) Manufacturing; (4) Electricity, gas and water; (5) Construction; (6) Wholesale and retail trade, restaurants and hotels; (7) Transport, storage and communication; and (8) Finance, insurance, real estate and business services. The series have been constructed with 1990 as the base year. For some industries data on TFP were not available at one-digit level. In such cases data from two-digit level were used as an approximation in order to create a balanced panel for each country under consideration.[1] The sample period spans from 1971 to 1990, and the cross-sectional panel includes a total of 1,760 observations.

1 Wholesale and retail were missing for Japan and the US, and were replaced by 61+62; finance was missing for West Germany and was replaced by 81+82.

Stockman (1988) suggests an appropriate framework which allows one to measure the relative importance of industry effects, country effects and international effects as the driving force of economic fluctuations (see FUNKE, HALL & RUHWEDEL, 1997) for an application to OECD two-digit industry output data). In his setup, OLS is applied to a panel, and changes in the dependent variable are decomposed into aggregate international shocks, industry-specific factors that are common across countries, and country-specific factors that are common across sectors. Stockman (1988) originally used his model to assess the relative contribution of sectoral and aggregate disturbances to industrial output growth in seven European countries, and in a similar vein Bayoumi and Prasad (1995) have recently compared the role of different types of shocks in driving economic fluctuations in Europe and the US.

Compared to Stockman's (1988) model, we adopt a more general specification which also allows for possible interactions between country and industry factors,[2] and which is effectively an "analysis of variance" (ANOVA) model. The estimated model is the following:

$$\Delta \ln(TFP)_{i,j,t} = \mu + \sum_{t=1971}^{1990} \tau_t D_t + \sum_{i=1}^{8} \sum_{t=1971}^{1990} \alpha_{it} D_{it} + \sum_{j=1}^{11} \sum_{t=1971}^{1990} \beta_{jt} D_{jt} + \sum_{i=1}^{8} \sum_{j=1}^{11} \gamma_{ij} D_{ij} + \varepsilon_{i,j,t} \quad (1)$$

where $i = 1, ..., 8$ represents the eight industries under consideration, $j = 1, ..., 11$ are the 11 OECD countries and $t = 1971, ..., 1990$ is the overall sample period. μ, τ, α, β, γ represent coefficients of the model. $\Delta \ln(TFP)_{i,j,t}$ is the dependent variable and simply measures growth as the first difference of the natural log of TFP. D_t is a time dummy which takes the value 1 for time period t and 0 otherwise, and this part of the model measures the contribution of the pure time effect in explaining variation in growth. It corresponds to international shocks which are common across all countries and industries. $D_{it} = 1$ for industry i and time period t and is 0 otherwise. This component of the model measures the interaction between time and indus-

2 A similar specification is adopted by COSTELLO (1993) to examine two-digit manufacturing data.

try, and thus represents shocks which are specific to industries. $D_{jt}=1$ for country j and time period t and is 0 otherwise, and explains that part of the variation in growth which corresponds to country-specific shocks. Finally, $D_{it}=1$ for industry i and country j, and takes the value 0 otherwise. This part of the model represents the interaction between industry and country which is unrelated to time. The disturbance term in the model is denoted by $\varepsilon_{i,j,t}$.

The measure of TFP that we use is obviously subject to numerous criticisms and in particular we make no adjustment for business cycle effects of labour hoarding or of market power. On the other hand capacity utilisation can be regarded in part as a consequence of conditions prevailing in a country as a whole and in part as a consequence of firms' technical ability; the lack of adjustment of TFP to capacity utilisation effects will therefore be appropriately accounted for in (1).

An ANOVA decomposition of the model in equation (1) was carried out for the sample period as a whole, and then its stability was checked by estimating it over two sub-samples, from 1971 to 1980 and 1981 to 1990. All sums of squares for the various components of the model were computed using the ordinary least squares criteria. In the estimation West Germany was arbitrarily chosen as the reference country; Finance, insurance, real estate and business services, as the reference sector, and 1990 as the base year. The empirical results were not sensitive to the choice of the base reference groups, and are discussed in the next section.

2. *EMPIRICAL RESULTS*

Tables 1 to 3 report the R^2 attributable to orthogonal regressors, which is a measure of the relative importance of the various types of shocks being considered, for the sample as a whole and the two subsamples. The results can be summarised as follows. All components of the model are statistically significant at the 5% level. On an overall basis the model explains 32% of total variation in TFP across the countries and industries in the

panel under consideration. International shocks account for 3.4 percent of the total R^2 of the model and are statistically highly significant. Industry- and country-specific shocks are also significant, accounting for 10 and 12 percent respectively of the explanatory power of the model. The interaction between industry and country which is unrelated to time effects is also highly significant, and contributes approximately 6.2 percentage points towards the overall R^2.

The picture presented above changes quite significantly when the stability of the above results is examined by estimating the model over the subsamples from 1971 to 1980 and from 1981 to 1990. As can be seen from Table 2, which refers to the earlier subsample, country- specific shocks and the interaction between country and industry factors are not statistically significant in the first of the two decades examined. However, international shocks and industry-specific shocks remain statistically significant at the 5% level. The overall R^2 for the model is 33% between 1971 and 1980. In terms of percentage points the contribution of international shocks and industry-specific shocks to the overall R^2 for this subsample changes only marginally when compared with the sample as a whole in Table 1.

The results for the subsample from 1981 to 1990 reported in Table 3 indicate that all components of the model are statistically significant at the 5% level. The R^2 of the model equals 43.5 percent, out of which approximately 20% represents the contribution of the interaction between country and industry factors. Thus this accounts for almost half of the total explained variation in TFP growth during the 1980s, which was a period of industrial policy changes in many countries. Industry-specific shocks remain statistically more significant than country-specific shocks between 1981 and 1990. International shocks now contribute 1.9 percentage points to the overall R^2, as opposed to 3.4 percentage points for the sample as a whole. Thus their influence on TFP growth appears to have diminished during the 1980s compared to the earlier decade, when the two oil shocks occurred. This is consistent with international shocks being comprised of common demand shocks as well as common technology shocks.

TABLE 1 - ANOVA TABLE FOR THE SAMPLE PERIOD AS A WHOLE FROM 1971 TO 1990

Source of variation:	Sum of Squares:	R^2:	F - value:	Degrees of Freedom:	Prob Value:
International shocks	0.318	0.034	3.49	(19, 1330)	(0.000)
Industry specific shocks	0.953	0.101	1.42	(140, 1330)	(0.002)
Country specific shocks	1.155	0.123	1.20	(200, 1330)	(0.039)
Country and industry factors	0.586	0.062	1.74	(70, 1330)	(0.000)
Total explained variation	3.012	0.320			
Total variation	9.401				

TABLE 2 - ANOVA TABLE FOR THE SUB-SAMPLE PERIOD FROM 1971 TO 1980

Source of variation:	Sum of Squares:	R^2:	F - value:	Degrees of Freedom:	Prob Value:
International shocks	0.220	0.039	4.05	(9, 630)	(0.000)
Industry specific shocks	0.607	0.107	1.44	(70, 630)	(0.014)
Country specific shocks	0.697	0.123	1.15	(100, 630)	(0.166)
Country and industry factors	0.352	0.061	0.83	(70, 630)	(0.831)
Total explained variation	1.876	0.330			
Total variation	5.681				

TABLE 3 - ANOVA TABLE FOR THE SUB-SAMPLE PERIOD FROM 1981 TO 1990

Source of variation:	Sum of Squares:	R^2:	F - value:	Degrees of Freedom:	Prob Value:
International shocks	0.070	0.019	2.34	(9, 630)	(0.013)
Industry specific shocks	0.345	0.093	1.49	(70, 630)	(0.008)
Country specific shocks	0.458	0.124	1.38	(100, 630)	(0.013)
Country and industry factors	0.733	0.199	3.16	(70, 630)	(0.000)
Total explained variation	1.606	0.435			
Total variation	3.692				

The above results suggest that on the whole industry-specific shocks are statistically more significant than country-specific shocks. The pattern of these shocks can be visualised on a year-by-year basis by examining the R^2 from the model below which is estimated for each year from 1971 to 1990:

$$\Delta \ln(TFP)_{i,j} = \mu + \sum_{i=1}^{8} \alpha_i D_i + \sum_{j=1}^{11} \beta_j D_j + \varepsilon_{i,j} \qquad (2)$$

where $D_i = 1$ for industry i and is 0 otherwise, and this component of the model measures the industry specific shocks; and $D_j = 1$ for country j and is 0 otherwise, and explains that part of the variation in growth which corresponds to country-specific shocks. The base reference groups are the same as for equation (1). In Figure 1 the R^2 for the model as a whole has been presented for each year in the sample period under consideration. The individual R^2s pertaining to country-specific and industry-specific shocks are presented in Figures 2 to 3 respectively. As can be seen from these graphs, the R^2 corresponding to industry-specific shocks rises relative to that for country- specific shocks in the 1980s. The same trend is apparent from Figures 4 to 6 which present the individual R^2s of country- and industry-specific shocks as a percentage of the total R^2 on a year-by-year basis.

FIGURE 1 - YEAR-BY-YEAR R^2 FOR COUNTRY & INDUSTRY SHOCKS FROM 1971 TO 1990

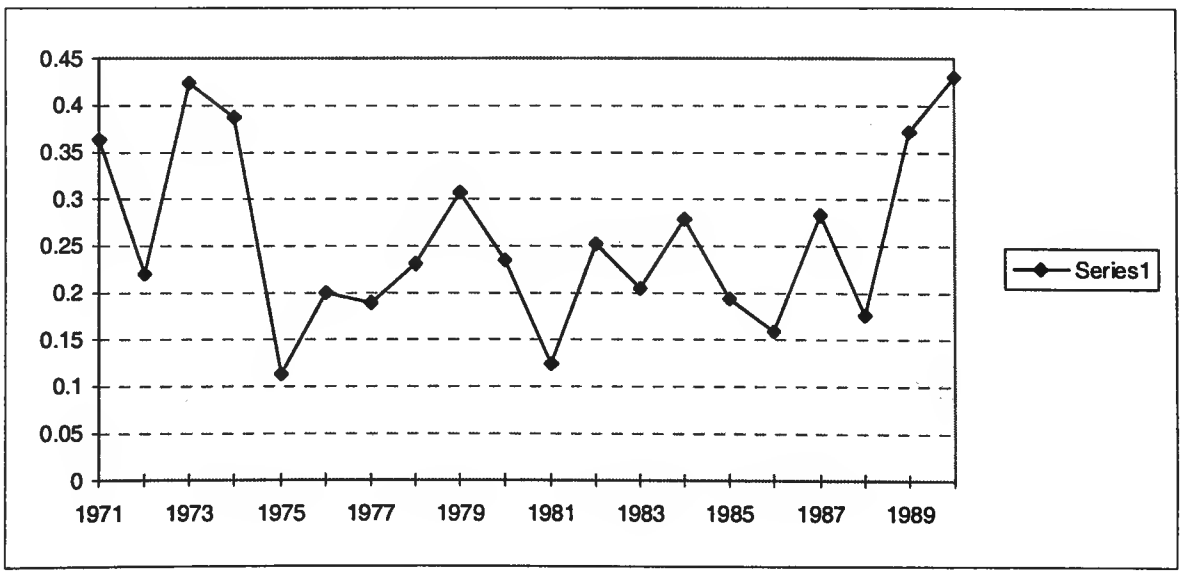


FIGURE 2 - YEAR-BY-YEAR COUNTRY-SPECIFIC R^2 FROM 1971 TO 1990

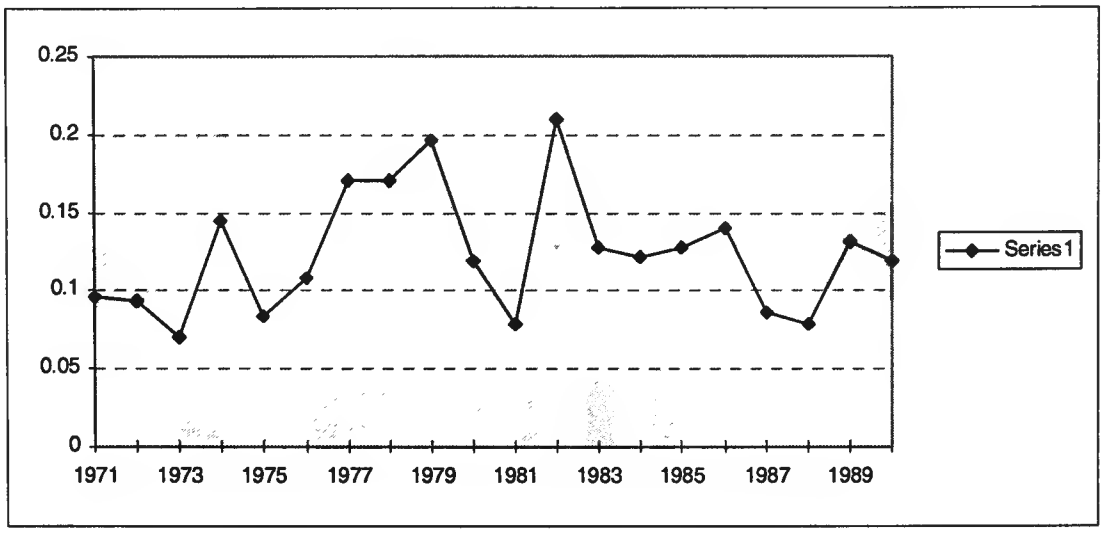


FIGURE 3 - YEAR-BY-YEAR INDUSTRY-SPECIFIC R^2 FROM 1971 TO 1990

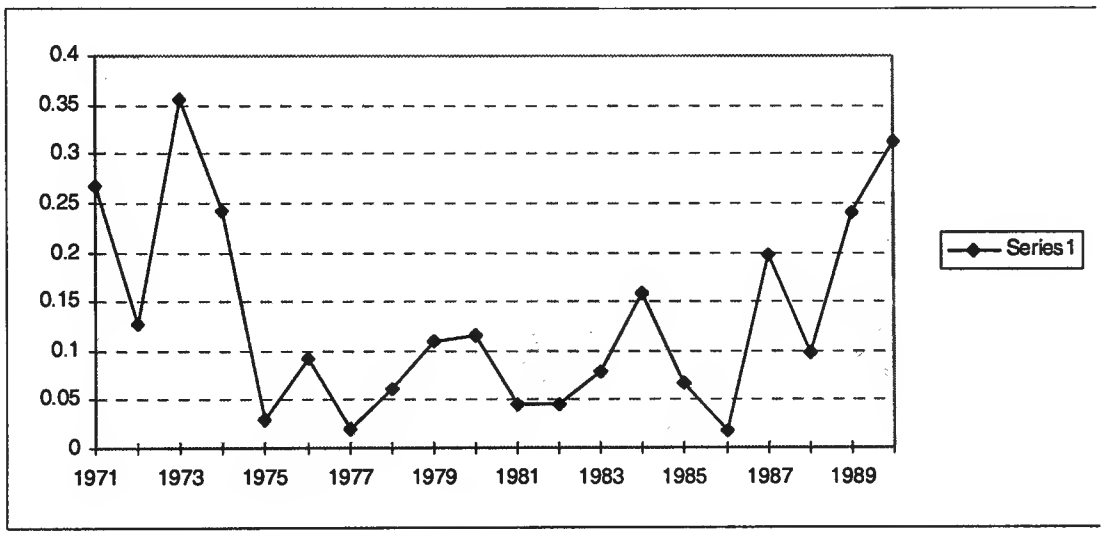


FIGURE 4 - YEAR-BY-YEAR COUNTRY-SPECIFIC R^2 AS % OF TOTAL R^2

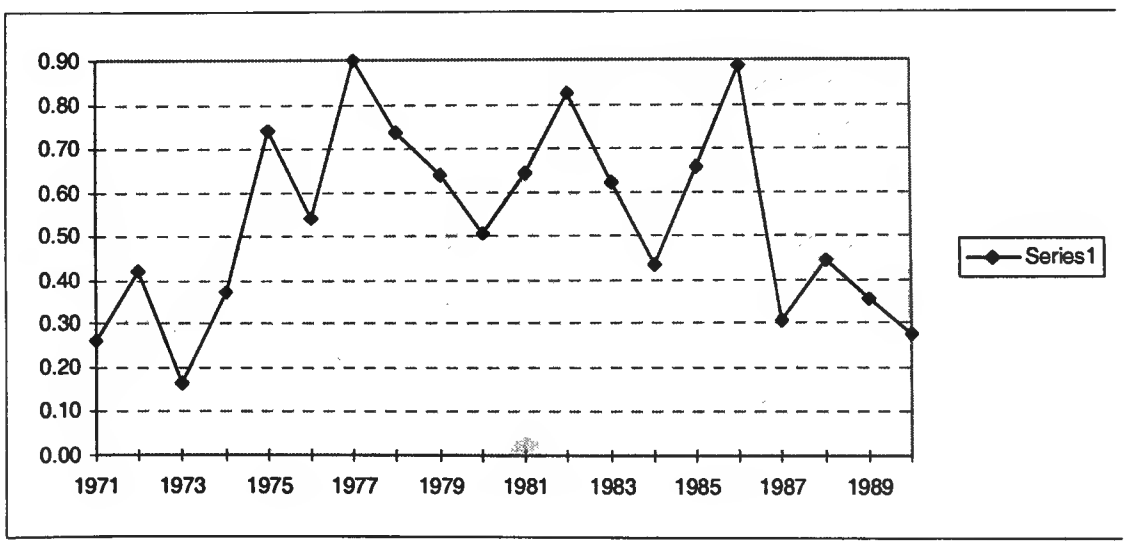


FIGURE 5 - YEAR-BY-YEAR INDUSTRY-SPECIFIC R^2 AS % OF TOTAL R^2

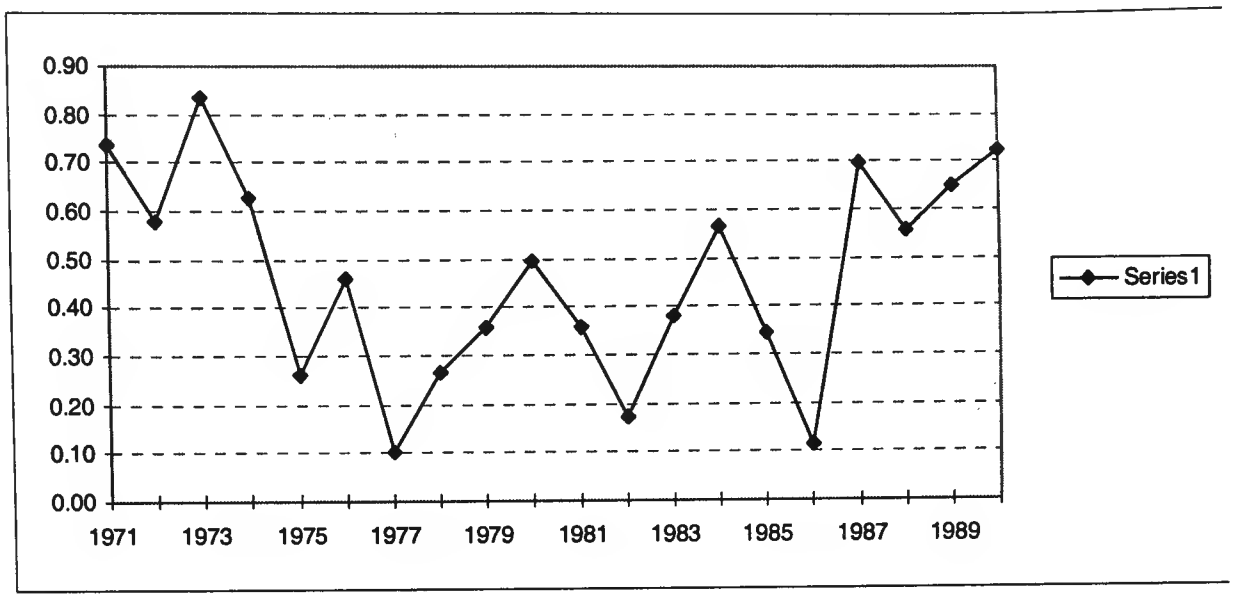
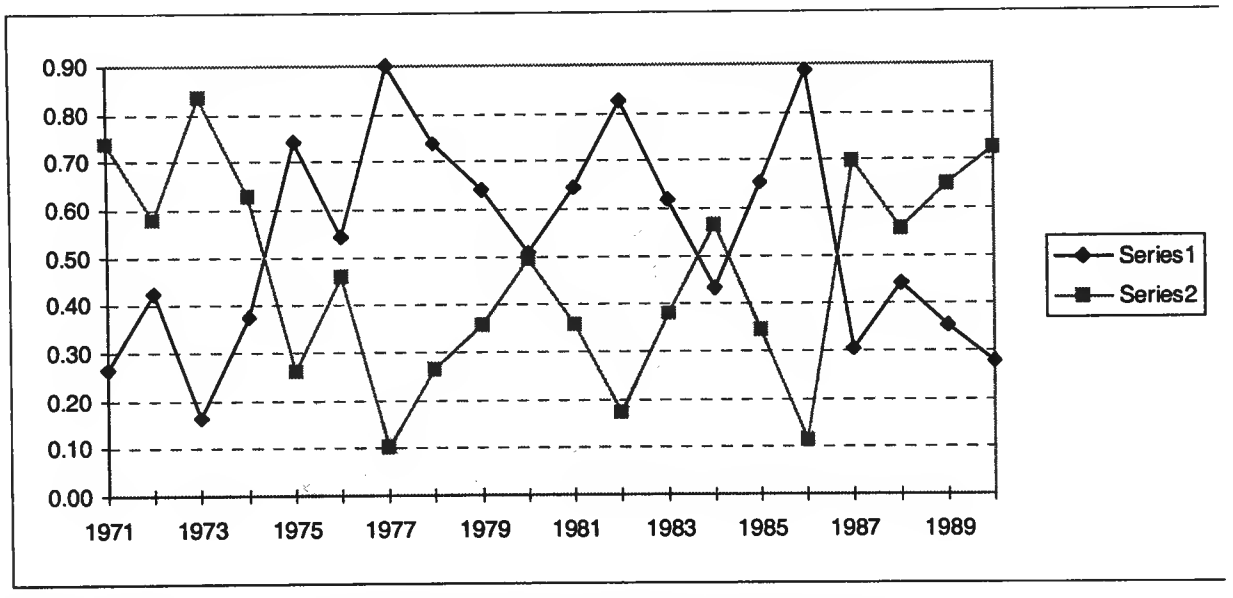


FIGURE 6 - YEAR BY YEAR COUNTRY- & INDUSTRY-SPECIFIC SHOCKS AS % OF TOTAL R^2



Note: Series 1: country-specific shocks; Series 2: industry-specific shocks.

CONCLUSIONS

This paper has presented some empirical evidence on the determinants of long-run growth in a number of OECD countries. An "analysis of variance" (ANOVA) model has been estimated using OECD one-digit industry data on total factor productivity (TFP) in order to assess the relative importance of industry-specific, country-specific and international shocks (as well as possible interactions between industry and country effects). The

results suggest that international factors are significant, although their contribution to TFP growth is small - country - and industry-specific shocks have the highest explanatory power over the whole sample period including the seventies and the eighties. Further, it appears that interactions between country and industry effects were the main driving force in the eighties, when the importance of country (relative to industry) effects also increased.

The fact that the better fit of the model in the second subsample mainly reflects idiosyncratic shocks can be interpreted as evidence against convergence, which is often seen as the result of more openness (see SACHS & WARNER, 1995). An alternative explanation of the idiosyncratic country effects is potentially to be found in the stochastic frontiers literature (see, e.g., AIGNER, LOVELL & SCHMIDT, 1977, and FARRELL, 1957). This allows for (a) exogenous technical progress in the production frontier function; (b) symmetric shocks around the production frontier due, for example, to unexpected demand shifts; (c) one-sided shocks due to inefficiency. If one allows the probability distribution of the latter shocks to be dependent on time, then it may be possible to assess convergence by examining the time path of such shocks for each country. Liu *et al.* (1998) find, however, that fixed effects for countries cannot be rejected even in the context of inefficiency shocks.

Our findings are consistent with those of other studies suggesting that international trade has only a minor impact on growth (see, e.g., KRUGMAN & LAWRENCE, 1993). Support for our industry results comes from a study on disaggregated German data by Lucke (1998). He finds that productivity shocks across sectors are not fully cointegrated; if they had been, then one would expect to see virtually no industry-specific effects in our study.[3] On the other hand, it is possible that firm-specific factors, such as firm investment decisions, not considered here, are more significant forces. On the whole, it would seem that globalisation has not played a major role

3 However there are some cointegrating relationships in his study, indicating that sector-specific shocks are not completely independent.

as one of the determinants of growth in the OECD area, and that theories of growth focusing on idea, trade and financial flows might not be of extreme relevance in explaining the experience of the industrial countries. However, they might be crucial to understand the process of growth in the South. In particular, a "new growth, new trade" framework might be appropriate to describe the gradual transition from an initial phase of development, characterised by specialisation in traditional goods, to subsequent phases in which first imitation and then innovation become more important (see CHUI, LEVINE & PEARLMAN, 1998). More empirical evidence, though, especially on the effects of international trade on wage differentials and employment, is required before drawing any strong conclusions (see the companion paper by CAPORALE & HAQ, 1998).

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