Testing the Linkages between Trade and Productivity Growth in a Panel of OECD Countries

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Abstract

We examine the effect of trade on productivity growth using data from nine manufacturing industries across twelve OECD countries over the period 1978-1997. Since causality between productivity growth and trade share runs both ways, geographical characteristics of countries are used to instrument for average bilateral trade volumes over the 20-year period. In addition, to exploit the time-series nature of the data and check the sensitivity of our results, we construct a panel data set and employ dynamic panel data techniques. After controlling for industry-specific heterogeneity, our results indicate that increased openness within industries, in particular higher import volumes, exerts a positive influence on productivity growth. However, the effect is rather small.

Key words: Trade; Total factor productivity (TFP) growth; Openness; Gravity equation; Manufacturing Industries

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1 Introduction

Does trade exert a positive influence on economic performance? This is a question of long-standing interest and a question that has become increasingly relevant as lower transportation costs and shifts toward freer trade have dramatically increased bilateral trade volumes. For many, the case for trade liberalization is clear (e.g. Bhagwati 1998) while others are more skeptical (Rodriguez and Rodrik, 1999). Despite numerous studies finding evidence of a positive link between trade and growth, the controversy has been far from settled. There are at least two reasons for this.

First, it has been difficult to establish a theoretical link between trade and growth. The issues of economic growth and trade have typically been treated independently of each other; dynamic models of closed-economies are the standard benchmark in the orthodox growth literature, while static open-economy models are the norm in the theoretical literature on trade. With the advent of new growth theory some authors have considered the implications of trade for growth (see, for instance, Grossman and Helpman, 1991; Rivera-Batiz and Romer, 1991 among others). However, even within these contexts the role of trade is limited; under the assumption that the cost of adopting existing technologies is less costly than innovating, attention centers on the role of trade as a vehicle for transmitting knowledge.

Second, the empirical literature on trade and economic performance has been plagued by serious data problems. Unsatisfactory measures of openness question the validity of observed links between trade policy and economic performance while direct attempts to establish the consequences of trade are unable to offer persuasive evidence in the face of bidirectional causality[1].

[1] See Rodriguez and Rodrik (1999).

In this paper we re-examine empirically the impact of trade on economic performance. However, our focus is on the consequences of trade for productivity rather than growth per se. The central contribution of this paper is its attempt to correct for biases on account of simultaneity between trade and productivity growth.

Existing empirical studies, which have focused on trade and productivity growth, have attempted to identify trade's effect by including trade directly in the right hand side of otherwise standard growth regressions. These findings are not necessarily persuasive since correlations between trade and productivity growth are not evidence of the effect of trade on the latter.

Specifically, studies which have examined the causal effect of openness on growth at an aggregate level, have typically found a positive link between the two (Levine and Renelt, 1992; Harrison, 1995; Edwards, 1998). However, when the focus has centered on the effect of trade on the performance of manufacturing industries across OECD countries, no consensus seems to have emerged. For instance, some studies support a strong impact of trade, especially of imports, on productivity growth (MacDonald, 1994; Keller, 1999) while other recent studies are unable to establish a significant effect of trade at all (Griffith *et al.*, 2004; Cheung and Garcia Pascual, 2004).

Our paper is in line with this recent literature (Griffith *et al.*, 2004; Cheung and Garcia Pascual, 2004) which explores, among other factors, the role of trade on productivity growth in manufacturing sector. The value-added of our approach is that it is explicitly designed to overcome some of the problems - not adequately addressed in previous studies - associated specifically with measuring the impact of trade. We do not try to offer any nuanced conclusions as to the role of trade, but simply to establish a link between the volume of trade and growth, if in fact such a link exists. As such, our approach tries to complement these important earlier studies cited above.

Our evidence is based on data from nine two-digit manufacturing industries in twelve OECD countries from 1978 to 1997. Two different estimation strategies to correct for possible biases arising on account of simultaneity in both cross-sectional and panel data are considered.

In our cross-sectional data, we use geographical characteristics of countries, namely size and proximity, to instrument for bilateral trading volumes. The instrument employed here was first suggested by Frankel and Romer (1999). Geography provides considerable information about the amount that countries trade, and since there is no likely channel through which it can affect productivity growth other than through trade, serves as a good instrument for trade.

As a check of the sensitivity of our findings we consider the impact of trading relationships on industries across time. We correct for biases associated with simultaneity by using appropriate GMM estimation procedures. This involves employing a set of internal instruments for all endogenous and predetermined variables in addition to the set of external instruments based on gravity models of trade.

Our cross-sectional evidence suggests that international trade has a sizeable and statistically significant impact on productivity growth. This relationship also seems to hold within industries over time. However, the evidence from GMM estimates points to import volumes as opposed to exports as the major factor in determining productivity increases.

The remainder of the paper proceeds as follows. Section 2 describes the empirical methodology employed and the data. Section 3 provides estimates for the effect of trade on productivity growth and discusses the results. Section 4 concludes.

2 Methodology

Measuring Productivity Growth and the Effect of Trade on Productivity Growth

The starting point for our analysis, which closely follows Griffith *et al*. (2004) and Scarpetta and Tressel (2002), involves calculating a measure of productivity growth. Suitable measures of output and factor inputs are thus required as well as measures of output elasticities of inputs, which are assumed to be equal to the income shares of capital and labor.

Following Caves *et al*. (1982), the level of total factor productivity growth (TFP) is measured as a superlative index number derived from a constant-returns-to-scale translog production function. Specifically, we can write TFP growth in industry *i*, country *j* and at time *t*, as:

$$TFP_{ijt} = \ln\left(\frac{Y_{ijt}}{\overline{Y}_{.jt}}\right) - \sigma_{ijt}\ln\left(\frac{L_{ijt}}{\overline{L}_{.jt}}\right) - \left(1-\sigma_{ijt}\right)\ln\left(\frac{K_{ijt}}{\overline{K}_{.jt}}\right) \tag{1}$$

where Y_{ijt} is real value-added, L_{ijt} and K_{ijt} are, respectively, inputs of labor and physical capital, and a bar above the variable denotes a geometric mean in industry *j* at time *t*. The variable $\sigma_{ijt} = \frac{1}{2}\left(\alpha_{ijt} + \overline{\alpha}_{jt}\right)$ is the average of the labor share in value-added country *i* and industry *j*, α_{ijt}, and the geometric mean of the labor share in industry *j*, $\overline{\alpha}_{jt}$.

The growth rate of TFP growth is then simply:

$$\Delta TFP_{ijt} = \Delta Y_{ijt} - \frac{1}{2}(\alpha_{ijt} + \alpha_{ijt-1})\Delta L_{ijt} - [1 - \frac{1}{2}(\alpha_{ijt} + \alpha_{ijt-1})\Delta K_{ijt}] \tag{2}$$

In estimating the impact of trade on productivity, we follow Griffith *et al.* (2004), and Scarpetta and Tressel (2002), and employ an empirical framework in which productivity growth, in any given industry, in any given country, is spurred by new technological innovations occurring at the frontier country, and through the diffusion of existing technologies. The frontier country for any given industry is defined as the country with the highest value of TFP within that industry and a country's distance from the technological frontier is simply calculated by subtracting the frontier country's TFP, TFP_{Fjt}, from TFP_{ijt}, i.e. $GAP_{ijt} = TFP_{ijt} - TFP_{Fjt}$.

We estimate two sets of regressions, using both cross-sectional and panel data. While there are some differences in specification across the two approaches, in each case the equation we estimate is essentially of the following form:[2]

$$\Delta TFP_{ijt} = \beta_1 \Delta TFP_{Fjt} + \beta_2 GAP_{ijt} + \beta_3 T_{ijt} + \beta_4 X_{ijt} + \varepsilon_{ijt}, \quad (3)$$

where ΔTFP_{ijt} is the growth rate of total factor productivity growth in country *i*, industry *j* at time *t*; ΔTFP_{Fjt} is the growth rate of total factor productivity growth in the frontier country *F*, industry *j* at time *t*; GAP_{ijt} is the difference in the total factor productivity growth rates of country *i*, industry *j* at time *t* from the frontier country for the same industry *j* at time *t* ($GAP_{ijt} = TFP_{ijt} - TFP_{Fjt}$); T_{ijt} is the trade share; X_{ijt} is a set of control variables; and ε_{ijt} is the error term.

In presences of technology transfer form the frontier country, *F*, in industry j, the estimated coefficient on ΔTFP_{Fjt} is expected to be positive and statistically significant while a negative and statistically significant estimated coefficient on GAP_{ijt} will indicate convergence among industries across countries.

Trade share (T_{ijt}) either in the form of exports or imports, is a proxy of growth-enhancing interactions (specialization, exchange of ideas through exports or acquiring foreign technology through quality imports) among industries across countries, acting as conduit for knowledge

[2] In the cross-sectional data, the time subscript is suppressed and in the panel data, the constant term is replaced with a country-industry-specific intercept. In both specifications, all variables are expressed in natural logarithms.

dissemination, and therefore, more open to trade industries should exhibit higher growth rates[3]. Therefore, the estimated coefficient on trade share (or on export share and import share) in our specification is expected to be positive. However, recent studies tend to find that the effect of trade on growth is rather ambiguous or insignificant (Rodriguez and Rodrik, 1999; Griffith *et al*., 2004; Cheung and Garcia Pascual, 2004).

In addition to trade, we consider a number of other control variables (X_{ijt}), namely, research and development (R&D), a proxy for the market structure (price-cost margin), sunk costs, and government spending that can possibly affect the total factor productivity growth. More specifically:

We include research and development expenditures (*R&D*) as a control variable since it stimulates innovation, facilitates imitation of new technologies and is considered to be an important factor in generating productivity growth according Schumpeterian models of growth and new growth theory (Romer, 1990; Grossman and Helpman, 1991).

Following Garcia Pascual and Cheung (2004), a control variable that we use here to capture the degree of monopolistic competition is the price cost margin (*PCM*). Specifically this variable is defined as:

$$PCM_{ijt} = \frac{Y_{ijt} - LC_{ijt}}{F_{ijt}}$$

where LC_{ijt} is the labor compensation and F_{ijt} is the value of total production. Thus, lower values of this variable correspond to increased competitiveness. The effect of market structure on productivity growth is ambiguous. Since incentives to innovate follow from the degree of rent that can be accrued from conducting research and development, much of the literature on new

[3] See Grossman and Helpman 1991a, 1991b, 1995; Edwards, 1992; Frankel and Romer, 1999 among others.

growth theory implies a negative relationship between increased competition and productivity growth. However, as Aghion *et al.* (1997) have argued lower profits place greater pressures on managers to adopt new technologies in order to survive, thus, increased competition could also positively impact on productivity.

We also include as a control variable the sunk costs. The presence of high sunk costs deters firms from entering the market. According to Dixit (1989), an over-investment strategy deters potential entrants and thus limits the extent of foreign direct investment, which is a channel for technology diffusion. Physical investment normalized by total production in industry i of country j at time t, is used as the proxy for sunk costs. Therefore, a negative relation is expected between sunk costs and productivity growth.

Lastly, we include government spending as a share of GDP as a control. This variable is commonly used in the empirical growth literature to explain cross-country differences in per capita income. The effect of government spending on productivity, however, can be ambiguous as it depends on the nature of spending. According to Barro and Sala-i-Martin (1995) productive spending - spending on education, infrastructure or some other form of productive capital - promotes growth while a nonproductive spending could obstruct growth.

Methodologically, this paper uses two econometric procedures to assess the relationship between trade and productivity growth and to deal with possible biases arising on accounting of simultaneity. First, we employ a pure cross-sectional, instrumental variable estimator. The trade share is instrumented by estimating a gravity equation, where bilateral trade flows are regressed on geographic characteristics. As in Frankel and Romer (1999), we rely on measures of distance, country-size, and population to isolate the exogenous component of trade flows. The fitted trade values are then aggregated across countries to create an instrument for the actual trade share. The dependent variable, which in this case is the average rate of productivity growth over the 20-year period from 1978 to 1997, is regressed against the average volume of (instrumented) trade over the same period, along with a number of other explanatory variables.

Second, we construct a panel dataset with data averaged over four five-year periods between 1978 and 1997. We then use the GMM estimator proposed by Arellano and Bond (1991) to extract consistent and efficient estimates of the impact of trade on productivity growth. The panel estimator conveys a number of advantages over the cross-sectional estimator. First, the panel estimator exploits the time-series variation in the data; it accounts for unobserved industry-specific heterogeneity, which might otherwise bias our estimates, and it corrects for the endogeneity of *all* the regressors, not just trade. However, the effectiveness of this estimator critically depends on how well lagged values instrument for the endogenous variables in our regression. Thus each estimation strategy should complement, rather than substitute for the other. Below, we describe the instruments used in the cross-sectional estimator and the GMM-estimation technique in more detail.

Correcting for Endogeneity in the Cross-Sectional Estimator

The gravity model was first applied to international trade by Tinbergen (1962)[4]. In its simplest form it posits that the volume of bilateral trade between two countries is a direct function of the output in each country and an inverse function of the distance between them. Specifically, we can write:

$$T_{nk} = \frac{Y_n^{\beta_n} Y_k^{\beta_k}}{D_{jnk}^{\gamma}},$$

[4] For theoretical justification for the Gravity Model see the study of Deardorff (1998).

where T_{nk} is the bilateral trade between countries *n* and *k*, Y_n and Y_k are measures of the value added in countries *n* and *k*, and D_{nk} is the distance separating the two countries. By taking logs this expression becomes: $ln(T_{nk}) = \beta_n \, ln\, Y_n + \beta_k \, ln\, Y_k - \gamma \, ln\, D_{nk}$. This can then be estimated using data across a cross-section of countries at a point in time, or using data averaged over a period of time. It is also standard to incorporate various dummies that capture the effects of common borders, as well as measures of cultural and linguistic distance, along with other variables.

Here we follow Frankel and Romer (1999) and estimate the following model:

$$ln[\frac{T_{jnk}}{Y_j}] = -\gamma \, ln\, D_{nk} + \beta_1 N_n + \beta_2 N_k + \beta_3 A_n + \beta_4 A_k + \beta_5 B_{nk} + v_{nk}\,, \qquad (4)$$

where T_{jnk} is the bilateral trade volume between countries *n* and *k* for industry *j*, D_{nk} is the distance between countries *n* and *k* measured as the great-circle distance between these countries' principal cities[5], Y_j is the value added of industry *j* in country *n*. N_n and N_k control for the size of the population in countries *n* and *k*, A_n and A_k are the areas of the two countries and B_{nk} is a dummy variable which takes the value one, if the two countries share a common border and v_{nk} the error term.

A number of important considerations arise within the current context. First, although the *United Nations Industrial Development Organization* (UNIDO) data provides a disaggregated measure of bilateral trade volume between any two countries in our sample and for any given industry, there is no way to infer which sectors the imports are coming from and which sectors the exports are going to. Thus, for instance, the bilateral export volume (normalized by value

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[5] The great circle distance, *D*, between two points with coordinates {lat1,lon1} and {lat2,lon2} is defined as : D= r* acos[sin(lat1)*sin(lat2)+cos(lat1)*cos(lat2)*cos(lon1-lon2)], where r = 6378.7 (kilometres) or 3963.0 (miles).

added) between Canada and USA for sector 31 averaged 0.021 over the 20-year period that our data spans. From this figure we cannot tell how much of this trade was intra-industry trade or inter-industry trade. Thus, we cannot estimate the value added of the sector or sectors in the US that are receiving imports from Canada's sector 31.

Second, since our data is observed at the industry-level, the measure of distance used to estimate the bilateral trade volume for some industry is the same for each of the industries within any two given countries. It is important therefore to allow the coefficient estimates to vary by industry. These differences in coefficient estimates can capture industry-specific factors related to average trade volumes and transportation costs. Aside from these differences, the exogenous component of trade that is captured in these regressions is the same across industries. Moreover, it is the same whether we focus on imports, exports, or the total volume of trade. This approach therefore is not perfect and without drawbacks and it is important to keep these caveats in mind when interpreting our results. The fitted values from equation (4) can be used to obtain an instrument for aggregate trade volume (either imports, exports, or their sum) for any given sector in any country. This is obtained by simply summing the fitted values for the bilateral trade volumes across countries.

The model we estimate fits the data very well for each industry. The R^2 varies between 0.62 and 0.85, and the correlation between actual bilateral trading volumes and fitted values varies between a low of 0.79 and a high of 0.92. Not surprisingly a similarly good fit is provided when we focus on just bilateral import volumes or bilateral export volumes (see Table 1).

Correcting for Endogeneity in the Panel Estimator

While the cross-sectional estimator helps us determine to what extent the cross-sectional variation in productivity growth can be attributed to the exogenous component of trading volumes, it has a number of drawbacks. First, the estimator does not utilize the time-series dimension of the data, and thus it does not provide an answer to whether greater openness within an industry over time has had affect on productivity within that industry. Second, the cross-sectional estimator does not correct for simultaneity biases arising on account of the inclusion of the other endogenous controls. Third, the omission of important controls could potentially bias our coefficient estimates. Fourth, the gravity model is not ideally suited for our purposes, since our data are disaggregated by industry. Moreover, it is difficult to distinguish the impact of imports versus exports, since the same measures of distance, size and population are utilized to pull out the exogenous component in each case.

Thus, to check the sensitivity of our findings, we employ the panel estimator proposed by Arellano and Bond (1991) to estimate equation (3) using data averaged over five-year windows. In this estimator country-specific effects are removed by first-differencing the data. Arellano and Bond (1991) then propose using an increasing sequence of lagged values of the endogenous and predetermined variables to correct for potential biases. Specifically, the endogenous variables lagged twice (or more) are valid instruments for their first differences.

Data

We constructed our panel data set by combining several sources. The main data source is the Organization for Economic Co-operation and Development (OECD) *International Sectoral Data Base* (ISDB), which provides information at the two-digit industry level on value added, labor and capital stocks.

We also draw on information from several other data sources. Trade data are derived from the OECD, and the United Nations Industrial Development Organization (UNIDO), *Bilateral Trade Database*. Data on R&D were retrieved from *Business Enterprise Expenditure on Research and Development* (BERD) by industry for each OECD country. Data on production and investment were retrieved from the OECD *Structural Analysis Dataset* (STAN) while data on government spending were retrieved from Eurostat, the Statistical Office of the European Commission. The same International Standard Industries Classification (ISIC) was used in all data sources as in the ISDB data, and information was available for the period 1978-1997 for the maximum number of industries, countries, and variables. Finally, data on population, area, common and border between the twelve OECD countries of our sample were obtained from Rand McNally (1993)[6].

Our sample consists of twelve countries (Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Sweden, U.K., and USA) over the period 1978-1997. For all countries, information is available for nine two-digit industries (ISIC 31-39). The industries considered in the analysis and their classification according to ISIC (revision 2), are presented in Table 2.

Mean rates of TFP growth by country and industry are reported in Table A2 in Appendix. Briefly, we could say that there is some heterogeneity in the rates of TFP growth across countries and industries. On average, in almost all industries, the identity of the frontier country remains constant while the identity of the country with the next highest level of relative TFP changes (Table A3 Appendix). As discussed above, it is not the identity of the frontier *per se* that matters in the econometric specification, but the measure of distance from the technological frontier which we use to capture the potential for technology transfer.

[6] See Table A1 in the Appendix for more details.

3 Results

Cross-Sectional Results

We begin by presenting the results from our benchmark cross-sectional model. In this case we regress the average total factor productivity growth in each industry against the average total factor productivity growth in the frontier country for that industry, the distance or gap to the frontier, a variable to control for the size of the industry and the volume of imports, exports, or total trade.

The results from the standard least squares estimator, presented in columns (1) to (4) of Table 3, provide quite strong evidence of convergence in productivity across our sample since the coefficient on the gap variable is negative and highly significant in all cases. Moreover, there is evidence also that technology spills over from the frontier. In particular, our results indicate that a one percent increase in TFP growth at the frontier translates to almost 0.4 percent increase in productivity in all other countries. These findings are quite consistent with earlier studies such as Griffith *et al.* (2004). In addition, a positive and significant coefficient on the size variable suggests possible scale effects.

While *no* attempts have been made to control for simultaneity at this point, the coefficient on the trade variables are quite informative. First, the marginal influence of trade appears to be quite small. For instance, one percent increase in the volume of exports (measured relative to value added), in the average industry, would raise productivity growth by approximately 0.0031 percent. Second, the impact of an increase in export volumes is roughly equivalent to the impact of an increase in imports (0.0034). Since the cross-sectional correlation between these two variables is high (0.66) this is perhaps not a surprising result. However, the inability to differentiate across these two variables could reflect omitted variables bias.

In column (5) we address this concern by including a number of other controls that have been found to have an important influence on the productivity performance of industries. Specifically, we add research and development expenditures, the price-cost-margin variable, government expenditures and sunk costs.

Introducing these additional controls has virtually no effect on the size of the coefficients on the trade variables. Although there is not enough variation in the data to find imports or exports by themselves to be insignificant. The total trade volume does appear to be statistically insignificant. The coefficients on the variables are consistent with earlier research and easily interpreted, however, in most of the cases, are statistically insignificant. The only exception is the estimated coefficient on PCM.

Hence, as column (5) shows, research and development appears to have a positive effect on productivity growth. The coefficient on the PCM variable is negative and highly significant suggesting that increased competition has a positive effect on productivity growth. Increases in government expenditures likewise also have negative consequences for productivity growth. This variable may be picking up government distortions that are harmful productivity growth. The negative coefficient on the sunk costs variable is also not unexpected and consistent with the earlier research (Garcia Pascual and Cheung 2004).

In Table 4, we repeat the same analysis as in Table 3, using our instrument-variables estimator based on the gravity model of trade (equation 4). In addition, we instrument for the variable size by using the value added in 1973. Columns (1) to (3), (6) correspond to columns (2) to (5) of Table 3. In the basic specification, that focuses solely on trade volumes, the size of the gap in productivity and the growth rate of productivity at the frontier, excluding all other controls, points to a strong statistically significant relationship between trade and productivity growth. In fact, the coefficients are estimated more precisely using our instrumental variables approach. With the inclusion of other controls, trade continues to appear to have a significant effect on productivity growth (columns 4-6). However, the coefficient on exports falls by half (0.0036). The effect of imports is largely unchanged with the inclusion of the additional controls (0.0053).

Comparing the OLS estimates to the IV estimates the later are not only statistically significant but also larger in size – almost doubled. However, prevailing views about the association between trade and productivity growth suggest that the IV estimates of trade's impact on productivity growth will be less than OLS estimates[7]. But contrary to what we expected, we found that IV estimates of trade's impact on income are actually higher than OLS estimates. A possible explanation for this finding is that OLS estimates are actually biased down. According to Frankel and Romer (1999), trade is a proxy - an imperfect measure - for all interactions that take place when industries involve in trade: exchange of ideas, specialization, spillover effects, and so on. Any measurement error leads to downward bias; as a result, it could cause an understatement of the effect of growth-enhancing interactions.

Panel Results

In order to explore the time series variation in the data and address some of the shortcomings of the cross-sectional estimator, we re-estimate our productivity growth equation using panel data. We estimate this specification using the first-difference one-step GMM-estimator developed by Arellano and Bond (1991).

[7] Due to omitted variable bias, a positive correlation between trade and error term in an OLS regression leads to upward bias in the OLS estimate of trade's effect. Since there is no reason to expect correlation between proximity and these various omitted country-industry characteristics, there is no reason to expect that the IV to suffer from the same bias.

The results, presented in Table 5[8], suggest somewhat different implications for the role of trade in productivity. In particular the results from columns (1) to (3), which correspond to the basic specification in the cross-sectional data, reveal a positive effect of imports on productivity growth. Industries benefit from increased imports perhaps because greater exposure to higher quality foreign goods lowers the costs of imitation, or places greater pressure on domestic firms to adopt new technologies and improve efficiency. However, our results also suggest that an increase in outward orientation and increased exporting has little or no positive influence on productivity. The inclusion of additional controls does not alter these results (columns 4-6). Imports continue to play a significant role on productivity growth (0.0106), whereas the coefficient of exports turns negative and continues to be statistically insignificant (-0.002).

Some of the results also differ in the panel specification. Note for instance, the distance to the frontier no longer has a statistically significant or even negative impact on productivity growth. Thus there is no evidence of convergence in productivity within the panel data. In part, this may reflect the more limited variation in productivity differentials over time as opposed to across industries. However, some caution needs to be exercised. This result is somewhat sensitive to the way in which this variable enters the regression.

Another notable difference between the cross-sectional and panel results is the coefficients on government spending and research and development. Government spending is now seen to have a positive effect on productivity growth, while the effect of research and development expenditures is negative. However, the coefficients on these variables are not statistically significant. The variable sunk costs, however, continues to be not only negative, as it

[8] We exclude from the panel analysis the variables *SIZE* and *PCM* since there is no variation in them over the period under investigation.

was in our earlier findings reported for the cross-sectional estimator, but also statistically significant in each of the specifications in columns (4) to (6).

Arellano and Bond (1991) suggest two tests to assess the validity of the model. Crucially, second-order serial correlation should be absent and the results meet that test. They also suggest a Sargan test for over-identifying restrictions. In the basic specification, the null hypothesis that over-identifying restrictions are valid cannot be rejected, this is not the case in the more general specification. While this is of some concern, it is well-known that in finite samples the Sargan test statistics obtained from the one-step Arellano-Bond estimator often over-reject the null in the presence of heteroskedasticity (see Arellano and Bond 1991)[9].

Sensitivity analysis suggested qualitatively similar findings when using alternative conditioning information sets, data at various frequencies and various sub-samples. In general, increased openness is found to have a statistically significant effect on productivity growth in the cross-sectional data. This is true for both import volumes and export volumes. However the inclusion of additional controls weakens the impact of exports. Within the panel data, only a robust link between import volumes and productivity growth is present. The effect of exports is limited.

4 Conclusion

The paper investigates the impact of trade on TFP growth in manufacturing sector across twelve OECD countries over the period 1978-1997. Although recently there have been a number of studies that examine the effect of trade on productivity growth in manufacturing sector, the

[9] While standard errors robust to heteroskedasticity can be obtained, the distribution of the Sargan test is unknown in this case. Thus, the Sargan test statistic reported for the one-step estimator should be treated with caution. For this reason, researchers sometimes rely on the Sargan test statistics from the two-step estimator, which in this case does not lead to a rejection of the null hypothesis that the over-identifying restrictions are in fact valid.

evidence that they provide is often based on the correlation between trade and productivity growth. An important concern for the evidence that these studies provide is the endogeneity of trade.

The paper attempts to address this problem by extracting the exogenous component of trade - due to geographic factors - to identify the effects of trade on productivity growth. Geography provides considerable information about the amount that countries trade, and since there is no likely channel through which it can affect productivity growth other than through trade, geographic serves as a good instrument for trade.

We employ two econometric methods. To assess the impact of exogenous component of trade on productivity growth, we use a sample with data averaged over the period under investigation. Additionally, to exploit the time-series nature of the data and to check the sensitivity of our results, we construct a panel data set and employ dynamic panel data techniques proposed by Arellano and Bond (1991). This procedure controls for possible endogeneity of the regressors and for industry specific effects in a dynamic, lagged-dependent variable model.

Overall, our results indicate that trade may have a positive influence on productivity growth. However this effect is small. There is also some indication that imports are more important for productivity growth than exports. It seems that industries benefit more form increased import since greater exposure to higher quality foreign goods lowers the cost of imitation or places greater pressure on domestic firms to adopt new technologies and improve efficiency. This finding comes across particularly strongly in our panel estimators, where the impact of exports on productivity growth is negligible.

An inherent limitation of the approach of "pure geography" as an instrument for trade that we considered in the cross-section model specification does not enable us to discuss the actual mechanisms though which exports and imports can affect growth. Future research should shed more light on the different channels through which exports and imports can affect productivity growth. Additional microeconomic work on the linkages between innovation, spillover effects, productivity growth and their connection to openness is essential in order to gain further insight on this issue.

Table 1. The Gravity Model: Assessing the Goodness of Fit

ISIC Code	Openness (imports + exports)		Import volumes		Export volumes	
	Correlation with actual values	R^2	Correlation with actual values	R^2	Correlation with actual values	R^2
31	0.85	0.72	0.80	0.63	0.86	0.73
32	0.91	0.83	0.88	0.77	0.92	0.85
33	0.80	0.64	0.76	0.58	0.91	0.83
34	0.79	0.62	0.81	0.66	0.90	0.79
35	0.92	0.85	0.94	0.88	0.92	0.85
36	0.89	0.80	0.90	0.81	0.91	0.82
37	0.90	0.80	0.86	0.80	0.92	0.84
38	0.90	0.82	0.93	0.86	0.91	0.84
39	0.84	0.72	0.87	0.75	0.84	0.71

Table 2. Manufacturing Industries included in the Analysis

ISIC Code	Manufacturing Industries
31	Food, Beverages and Tobacco
32	Textiles, Apparel and Leather
33	Wood Products and Furniture
34	Paper, Printing and Publishing
35	Chemical Products
36	Non Metallic Mineral Products
37	Basic Metal Industries
38	Fabricated Metal Products
39	Other Manufacturing

Table 3. Cross-Sectional Regressions, OLS

Dependent variable: TFP growth (*t-statistics*)	(1)	(2)	(3)	(4)	(5)
Frontier TFP growth	0.4113	0.3820	0.3832	0.3851	0.2783
	(4.03)	*(3.69)*	*(3.70)*	*(3.76)*	*(2.80)*
Gap	-0.0172	-0.0200	-0.0176	-0.0185	-0.0175
	-(5.85)	*-(5.35)*	*(4.57)*	*-(4.96)*	*-(4.58)*
Size		0.0027	0.0021	0.0027	0.0065
		(1.92)	*(1.71)*	*(2.00)*	*(2.67)*
Import share		0.0034			
		(1.86)			
Export share			0.0031		
			(1.80)		
Openness				0.0036	0.0023
				(2.04)	*(1.36)*
R&D					0.0247
					(0.68)
PCM					-0.0103
					-(4.96)
Government					-0.0042
					-(1.54)
Sunk cost					-0.0014
					-(0.65)
R squared	0.37	0.40	0.40	0.40	0.52
# obs.	90	90	*90*	90	87

Note: All coefficients are estimated at significance level of 5%; *t*-statistics are reported between parentheses.

Table 4. Cross-Sectional Regressions, Instrumental Variables Regression

Dependent variable: TFP growth (*t-statistics*)	(1)	(2)	(3)	(4)	(5)	(6)
Frontier TFP growth	0.3502	0.3532	0.3629	0.2756	0.2508	0.2672
	(3.27)	*(3.33)*	*(3.48)*	*(2.72)*	*(2.45)*	*(2.66)*
Gap	-0.0206	-0.0163	-0.0180	-0.0206	-0.0160	-0.0174
	-(5.41)	*-(4.11)*	*-(4.78)*	*-(4.94)*	*-(4.01)*	*-(4.51)*
Size	0.0042	0.0030	0.0038	0.0096	0.0063	0.0075
	(2.42)	*(2.26)*	*(2.52)*	*(3.05)*	*(2.65)*	*(2.94)*
Import share	0.0062			0.0053		
	(2.38)			*(1.99)*		
Export share		0.0055			0.0036	
		(2.59)			*(1.82)*	
Openness			0.0058			0.0042
			(2.65)			*(2.02)*
R&D				0.0061	0.0225	0.0173
				(0.16)	*(0.61)*	*(0.47)*
PCM				-0.0096	-0.0099	-0.0099
				-(4.42)	*-(4.64)*	*-(4.69)*
Government				-0.0062	-0.0036	-0.0043
				-(2.10)	*-(1.31)*	*-(1.55)*
Sunk cost				-0.0012	-0.0019	-0.0013
				-(0.55)	*-(0.87)*	*-(0.63)*
R squared	0.38	0.38	0.39	0.51	0.51	0.51
# obs.	90	90	*90*	87	87	87

Note: All coefficients are estimated at significance level of 5%; *t*-statistics are reported between parentheses.

Table 5. Panel Regressions, GMM-Estimator

Dependent variable: TFP growth (*t-statistics*)	(1)	(2)	(3)	(4)	(5)	(6)
Frontier TFP growth	0.2548	0.2094	0.2226	0.4131	0.3815	0.3984
	(1.66)	*(1.30)*	*(1.39)*	*(3.92)*	*(3.61)*	*(3.77)*
Gap	0.0130	0.0043	0.0099	0.0190	0.0034	0.0156
	(0.99)	*(0.30)*	*(0.71)*	*(1.01)*	*(0.17)*	*(0.77)*
Import share	0.0093			0.0106		
	(1.83)			*(1.91)*		
Export share		0.0047			-0.0020	
		(0.46)			*-(0.17)*	
Openness			0.0055			0.0045
			(1.50)			*(0.97)*
R&D				-0.0729	-0.4751	-0.1664
				-(0.09)	*-(0.59)*	*-(0.21)*
Government				0.0302	0.0554	0.0381
				(0.96)	*(1.58)*	*(1.13)*
Sunk cost				-0.0300	-0.0445	-0.0355
				-(1.86)	*-(2.71)*	*-(2.03)*
1^{st} order serial correlation *p-value*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
2^{nd} order serial correlation *p-value*	*0.59*	*0.41*	*0.52*	*0.76*	*0.99*	*0.78*
Sargan J *p-value* J	*0.64*	*0.85*	*0.74*	*0.09*	*0.08*	*0.06*

Note: All coefficients are estimated at significance level of 5%; *t*-statistics are reported between parentheses.

Appendix

All data are annual, for the period 1973 – 1997, and collected from the following sources:

Table A1. ***Variables: Definitions and Sources***

VARIABLE	DESCRIPTION	UNITS MEASURED	SOURCE
VA	VALUE-ADDED	CONSTANT PPPS, 1990; BN $ US	*ISDB* (OECD, 1999)[10]
PROD	PRODUCTION (SALES)	CONSTANT PPPS, 1990; BN $ US	*STAN* (OECD, 2002)[11]
K	GROSS CAPITAL STOCK	CONSTANT PPPS, 1990; BN $ US	*ISDB* (OECD, 1999)
L	ACTUAL HOURS WORKED (HWA)	THOUSANDS OF ACTUAL HOURS WORKED ON AVERAGE PER YEAR	*ISDB* (OECD, 1999)
LC	LABOR COMPENSATION	CONSTANT PPPS, 1990; BN $ US	*ISDB* (OECD, 1999)
R&D	EXPENDITURE ON R&D SHARE	RATIO (R&D/VA)	*BERD* (OECD, 2001)[12]
EXP, IMP	EXPORTS SHARE IMPORTS SHARE	RATIO (EXP/VA) RATIO (IMP/VA)	*ISDB* (OECD, 1999) *UNIDO*, 2002[13]
PCM	PRICE-COST MARGIN	$PCM = \frac{VA - LC}{PROD}$	CONSTRUCTED
I	PHYSICAL INVESTMENT	CONSTANT PPPS, 1990; BN $ US	*STAN* (OECD, 2002)
GOV	GOVERNMENT SPENDING	CONSTANT PPPS, 1990; BN $ US	EUROSTAT, 2002

[10] **ISDB**, International Sectoral Database (OECD, 1999, statistical compendium, cd-rom)
[11] **STAN** Database for Industrial Analysis (OECD, 2002, statistical compendium, cd-rom)
[12] **BERD**, Business Enterprise Expenditure on Research and Development (OECD, 2001, statistical compendium, cd-rom)
[13] **UNIDO**, United Nations Industrial Development Organization, *Bilateral Trade Flows*, 2002

SUNK	SUNK COST	SUNK = I / PROD	CONSTRUCTED
A, N, B	AREA, POPULATION, COMMON BORDER	SQUARED MILES, MILLIONS, DUMMY	RAND (1993)[14]

Table A2. Mean Annual Growth Rate of TFP, 1978-1997 (%)

	31	32	33	34	35	36	37	38	39	MEAN	MIN	MAX
CAN	0.202	0.249	0.404	0.317	-0.255	-0.176	0.049	-0.051	0.406	0.212	-0.255	1.176
DNK	-1.109	-1.171	-0.902	-0.924	-1.237	-1.172	-2.510	-1.164	-1.108	-1.289	-2.510	-0.715
FIN	-1.432	-1.307	-1.015	-0.919	-1.509	-1.324	-1.478	-1.336	-1.011	-1.422	-2.886	-0.919
FRA	0.606	0.908	0.428	0.646	0.844	0.631	0.544	0.670	0.321	0.615	0.270	0.908
GER	0.896	0.864	1.091	0.595	1.299	1.013	1.369	1.119	0.311	0.979	0.311	1.369
ITA	0.432	1.402	0.880	-0.044	0.359	0.922	0.439	0.429	-0.743	0.419	-0.743	1.402
JAP	1.271	0.552	0.068	0.062	1.100	1.054	1.485	1.048	2.721	1.084	0.062	2.721
NLD	-0.507	-0.840	-0.749	-0.325	-0.236	-0.725	-0.889	-0.526	-0.806	-0.654	-1.050	-0.236
NOR	-1.350	-2.063	-1.434	-1.035	-1.534	-1.256	-1.283	-1.438	-1.012	-1.314	-2.063	-1.003
SWE	-0.762	-1.102	-0.181	-0.372	-0.671	-0.901	-0.795	-0.512	-1.765	-0.634	-1.765	0.004
UK	0.555	0.819	0.054	0.823	0.731	0.765	1.232	0.428	0.292	0.601	0.054	1.232
USA	1.493	1.719	1.879	1.875	1.632	1.270	1.654	1.622	1.701	1.612	1.270	1.879

31: Food, Beverages and Tobacco; 32: Textiles; 33: Wood; 34: Paper; 35: Chemicals; 36: Non-Metallic Minerals; 37: Basic Metals; 38: Fabricated Metals; 39: Other Manufacturing

Table A3. Leading Industries and Countries, 1978-1997 (TFP growth)

	31	32	33	34	35	36	37	38	39
First	USA	USA	USA	USA	USA	USA	USA	USA	JAP
Second	JAP	ITA	GER	UK	GER	JAP	JAP	GER	USA
Last	FIN	NOR	NOR	NOR	NOR	FIN	DNK	NOR	SWE

31: Food, Beverages and Tobacco; 32: Textiles; 33: Wood; 34: Paper; 35: Chemicals; 36: Non-Metallic Minerals; 37: Basic Metals; 38: Fabricated Metals; 39: Other Manufacturing

[14] ***Rand, M.*** Quick Reference World Atlas. Chicago: Rand McNally, 1993.

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