Trade and Productivity Reconsidered:
An Industry and Aggregate Perspective

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August 2006

Abstract: We use a sample of 14 OECD countries to test for the effect of trade on productivity at different levels of aggregation: a sample of 15 manufacturing industries, aggregate manufacturing, services, and the total economy. Endogeneity concerns are accounted for using the geographical component of trade as instrument as suggested by Frankel and Romer (1999). We find that trade increases productivity, even if country-fixed effects such as the quality of institutions are controlled for. Estimates at the aggregate manufacturing level turn out much larger, emphasizing the role of inter-industry spillovers. We cannot identify, however, important spillover effects between manufacturing and services. The aggregate estimates suggest that an increase in openness by 1 percent raises productivity by 0.2 percent.

JEL Classification: F14, F43, L60

Keywords: Trade, Productivity, Manufacturing, Services

I. Introduction[1]

The relation between trade and productivity has always been at the heart of international economics. Theoretical arguments can be traced back at least to Adam Smith's famous dictum that the division of labour is limited through the size of the market. The literature has emphasized several additional channels via which trade influences productivity: the exploitation of increasing returns from larger markets (e.g. Balassa, 1961), the transmission of international technology spillovers (e.g. Coe and Helpman, 1995), as well as the pro-competitive effect of international trade (e.g. Bhagwati, 1965).

Numerous empirical studies have confirmed a positive correlation between trade and income. Lewer and Van den Berg (2003), in a comprehensive literature survey, find a surprisingly robust result in many cross-section and time series studies: "A one percentage point increase in the growth of exports is associated with a one-fifth percentage point increase in economic growth." (Lewer and Van den Berg, 2003, p. 363). However, endogeneity concerns and the absence of convincing instruments have cast doubts on whether the observed correlation actually reflects a causal relationship.

In recent years substantial progress has been made in overcoming these endogeneity concerns: Frankel and Romer (1999) argue that geography affects income only via trade and suggest using the geographical component of aggregate trade as instrument. Using data from cross-section of 150 developed and less developed countries for 1985, they find that the least squares results are not invalidated by the instrumental variable estimates. In contrast, the estimated effect of trade on productivity even increases if endogeneity is accounted for, though the estimates turn out only moderately significant. They find that a one percentage point higher trade share increases GDP per capita by some 2 percent, implying an elasticity of

[1] We wish to thank David Romer for very helpful comments on an earlier draft.

some 1.5. These results were basically confirmed by Irwin and Terviö (2002) for alternative reference years from the twentieth century, ranging from 1913 to 1990.

Still, there are at least two open points: Rodriguez and Rodrik (2001) and Rodrik et al. (2004) question the validity of the instrument (particularly in cross sections with strongly heterogeneous countries); they also argue that trade is insignificant once institutional quality is controlled for and that the positive effect of trade in previous studies may simply capture omitted institutional characteristics. Similarly, in Irwin and Terviö (2002) the effect of trade on productivity is not robust against including distance from the equator, a proxy for Western influence according to Hall and Jones (2002). Parts of these concerns on the relationship between trade and income have been addressed in a recent paper by Alcala and Ciccone (2004). They advocate the use of real rather than the nominal openness, which may be a distorted measure of openness as a result of the trade-related Balassa-Samuelson effect. They find (real) trade to be a significant determinant of productivity even when institutions are controlled for.

The second open issue refers to the channels through which trade affects productivity. While much care has been devoted to the econometric issues in estimating the productivity effects of trade from reduced form equations, the relevance of the particular mechanisms is still unclear: What are the channels via which trade affects income? While economic theory has much to say on this, empirically the link between trade and productivity is still largely a black box.[2]

We reinvestigate the relation between trade and productivity, applying the empirical approach suggested by Frankel and Romer (1999). However, we focus on a sample of

[2] One notable exception is Wacziarg (2001), who uses a simultaneous equation approach to identify the channels via which trade affects economic growth. He finds that trade raises growth mainly by accelerating the accumulation of physical capital, while enhanced technology transmission and improvements in macroeconomic policy account for smaller effects.

industrialized OECD countries – which mitigates, the relevance of the Rodriguez and Rodrik critique – and use both data at the industry and aggregate level. This allows us to make two new contributions: First, in the models using industry data we can control for country-specific effects such as institutional quality without requiring an explicit measurement of these institutions. Second, our industry-specific specification narrows the hypothesis, ruling out effects that materialize across industries; by comparing the industry-specific estimates with more aggregate ones, we can provide an assessment on the relevance of such inter-industry spillovers.

The results suggest that trade has a statistically significant and robust effect on productivity in manufacturing. For most models, our instrument – the geographical component of industry trade – is of high quality, yielding comparably precise and highly significant estimates. We also find that inter-industry spillovers are important within manufacturing and services, but that there are hardly spillover effects between manufacturing and services. The aggregate estimates suggest that an increase in openness by 1 percent raise productivity by 0.2 percent; this is very close to the average results found in the survey by Lewer and Van den Berg (2003).

The remainder of the paper is organized as follows. Section II sets up the empirical model. Section III constructs the instrument for trade. Section IV presents the estimates of the relation between trade and productivity at different levels of aggregation and compares the results. Section V summarizes the results and concludes.

II. Trade and Productivity: The Basic Empirical Model

Our empirical model to estimate the relationship between trade and productivity is in line with Frankel and Romer (1999). The basic idea is that the effects of openness on productivity can be estimated from a simple model that relates GDP (Y) per worker (L) to country size and trade:

$$\ln(Y/L)_i = a + b_1 \ln Trade_i + b_2 Size_i + e_i \,. \quad (1)$$

The parsimonious specification of equation (1) ensures that b_1 captures all channels via which trade effects productivity, including indirect effects such as an induced increase in competition or investment. A drawback is that *Trade* is likely to be correlated with the error term in equation (1). Countries that trade more may be more productive for reasons other than trade. As a result, the least squares estimate of the effect of trade on productivity is expected to be (upward) biased due to simultaneity and omitted variables. It has been argued that this upward bias might be attenuated or even dominated by a downward bias due to measurement error, since *Trade* is only a poor proxy for international interactions.

To overcome the endogeneity problem of equation (1), Frankel and Romer suggest using an aggregate measure of proximity (Z^{Trade}) as instrument for *Trade*, that is the geographical trade share, which is derived from a bilateral gravity model including geographical variables (distance, country size, dummies for common border or landlockedness) only. The identifying assumption is that there is no direct effect of geography on income other than through trade, once country size is controlled for.[3]

The approach pursued in this paper differs from previous studies in two important respects: First, in contrast to Frankel and Romer (1999) who use a large sample of 150 countries we focus on a sample 14 OECD member states (AUT, BEL, DEU, DNK, ESP, FIN, FRA, GBR, GRC, ITA, NLD, NOR, SWE, USA). The choice of a sample of "homogenous"

[3] Rodriguez and Rodrik (2001) have challenged this assumption, arguing that geography may be related to income via i) its effect on public health, ii) the quality of institutions, and iii) the quantity and quality of institutions. This may in fact be a problem in large cross sections including developed and less developed countries, but is less relevant for our sample of fourteen industrialized OECD countries. In addition, we will control for these channels by including country-specific fixed effects.

countries with similar institutions makes it unlikely that our trade variable captures unobserved institutional heterogeneity.

Second, in contrast to previous studies we investigate model (1) at the industry level, using data from 15 manufacturing industries (See Table A1 in the Appendix for an overview). The most important advantage is that this allows us to control for country-specific effects in a cross section setting, while maintaining the time-invariant geography based instrument. Since measurement of institutional quality is surrounded by considerable uncertainty, this is probably the best way to ensure that the estimated effect of trade does not capture (country-specific) institutional characteristics. Our starting point is the following basic empirical model:

$$\ln y_{ik} = a_k + b_1 Trade_{ik} + b_2 L_{ik} + e_{ik}, \qquad (2a)$$

where y_{ik} denotes productivity (in terms of value added per worker), and L_{ik} is employment; i is the country and k the industry index; a_k is an industry-specific intercept, capturing cross-industry variation in labour productivity unrelated to market size and trade, e.g. as a result of differences in capital-labour ratios. Our cross-section data refer to averages over the period 1995 to 2000.

For *Trade* we will use three alternative measures: the ratio of exports to production (x), the ratio of imports to production (m), and the ratio of exports plus imports to production (mx). At the aggregate level these variables are typically highly correlated and yield the same results; at the industry level, the correlation is less pronounced, so that it is worth considering the alternative results for all three measures.[4]

[4] Since no industry-specific deflators are available we have to use nominal openness rather than 'real' openness as advocated by Alcala and Ciccone (2004). For our sample, which includes mainly industrial countries with a similar level of development, this is not a major drawback, since the trade related Balassa-Samuelson effect is usually much less relevant here.

A natural choice for the size measure at the industry level is employment in the respective industry (L_{ik}). Intuitively, this choice emphasizes the role of economies of scale. What Frankel and Romer (1999) have in mind when including country size, however, is that country size acts as a proxy variable for unobservable within-country trade. Since industries also deliver intermediates to other industries, it is not the size of the own sector but that of the whole economy which is the relevant determinant of within-country trade. Following this logic we go on to include country size (in terms of population and area) in model (2a) as well, yielding

$$\ln y_{ik} = a_k + b_1 Trade_{ik} + b_2 \ln L_{ik} + b_3 \ln Pop_i + b_4 Area_i + e_{ik} . \tag{2b}$$

In our final, and most general model, we include country-specific effects m_i in equation (2a):

$$\ln y_{ik} = a_k + b_1 Trade_{ik} + b_2 \ln L_{ik} + m_i + e_{ik} . \tag{2c}$$

Of course, population and area, as well as all other country-specific measures such as institutional quality are now captured by m_i. It will be interesting to observe that change in the parameter estimates (particularly b_1) across the specifications, which gives an idea by how much trade variables capture effects other than trade.

It should be borne in mind that models (2) relate industry-specific productivity (in terms of value added per worker) to industry-specific openness. While increases in productivity in industry i do not necessarily increase productivity in industry j (even if i uses the output of j as intermediate good), there are still channels that may operate *across* industries: Specialization according to comparative advantage would be reflected in an increase in inter-industry rather than intra-industry trade; and as already emphasized by Balassa (1961, p. 131), external economies of scale may also be of the inter-industry type. By ruling out these inter-industry and general equilibrium effects, the hypothesis expressed by our industry specific model (2) is clearly narrower than the corresponding model at the aggregate level (1), and one would expect the effect of trade on productivity at the industry level to be smaller. This is another advantage of using industry data: Estimating the model at different levels of aggregation and comparing the results sheds some light on the question, how and via which channels trade affects productivity.

III. Construction of the Instrument

1) The Geographical Gravity Model

Frankel and Romer (1999) argue that geography is an important determinant not only of bilateral but also of overall trade. At the same time it is difficult to think of any channel other than international trade via which geographical characteristics may affect income. This is the rationale for constructing the instrument as 'geographical component' of aggregate trade, which is calculated from the predicted values of a geographical gravity model, whose regressor matrix (**X**) includes geographical variables only:

$$\begin{aligned} &\ln Trade_{ik}^{j} = \mathbf{a}'_{k}\mathbf{X}_{ij} + J_{ij}^{k} = \\ &= a_{0k} + a_{1k}Dist_{ij} + a_{2k}Pop_{i} + a_{3k}Area_{i} + a_{4k}Pop_{j} + a_{5k}Area_{j} + a_{6k}(LL_{i} + LL_{j}) + a_{7k}CB_{ij} + J_{ij}^{k} \end{aligned} \tag{3}$$

Our approach differs from Frankel and Romer only by using industry-specific bilateral trade flows instead of total trade; as a result we obtain an industry-specific instrument Z_{ik}^{Trade} as well. In equation (3), $Trade_{ik}^{j}$ is the ratio of trade (exports, imports or exports plus imports) between country *i* and country *j* to country *i*'s production in industry *k*, *Dist* is distance, *Pop* is population, *LL* is a dummy for landlocked countries, and *CB* is a common-border dummy.

To obtain our instrument Z_{ik}^{Trade}, that is the geographical component of (aggregate) trade by industry, the predicted values for the bilateral trade shares are aggregated as follows:

$$Z_{ik}^{Trade} = \sum_{j=1}^{J} q_{k} e^{\mathbf{a}'_{k}\mathbf{X}_{ij}} , \tag{4}$$

where $\boldsymbol{\alpha}_k$ is the estimate of α_k from (3); q_k is a correction factor required to obtain consistent predicted values for the levels of $Trade_{ik}^{j}$ from the estimates in log form.[5] Using (4) we calculate industry-specific trade shares for each of the 14 countries; the summation in (4) runs not only over the (44) countries for which we have bilateral trade data, but over all countries for which data on the variables in $\mathbf{X}$ are available (additional 179 countries).[6]

2) Estimation Results

Our sample comprises 14 countries (i) and 15 manufacturing industries (k). Equation (3) is estimated separately for each of the 15 industries, as well as for aggregate total manufacturing and total services. We have bilateral trade data by industry with 44 partner countries (j, $j \neq i$) covering some 90 percent of trade on average. Trade and production data are averages over the period 1995 to 2000 and are taken from the STAN database of the OECD. A detailed description of the data is given in the Appendix.

< Table 1 here >

Table 1 shows the estimates of gravity equation (3) for 15 manufacturing industries, aggregate manufacturing, and aggregate services. Results are given for the export ratio (x), but the estimates using the ratio of imports to production (m) and the ratio of imports and exports to

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[5] Under normality q_k is equal to $E[e^{\varepsilon_{ij}^{k}}] = e^{(\hat{\sigma}_k^2/2)}$, where $\hat{\sigma}_k^2$ is a consistent estimator of the variance of ε_{ij}^{k}. To avoid making distributional assumptions we follow the approach suggested by Wooldridge (2003, p. 207ff.) and estimate q_k from a regression of $Trade_{ik}^{j}$ on $e^{\boldsymbol{\alpha}_k \mathbf{X}_{ij}}$ through the origin. Since industry dummies are included in all our regressions, however, the correction does not affect the coefficients of the variables of our interest (*Trade*, *Pop*, *Area*) in the main model.

[6] As mentioned above, however, more than 90 percent of trade is covered by the countries for which bilateral trade data are available.

production (*mx*) as dependent variable turned out qualitatively similar and is omitted here for brevity.

As expected distance has a large negative effect on trade (defined as ratio of exports to production). The elasticity of trade with respect to distance ranges from -0.425 to -1.327; for industries with a larger weight/value ratio (e.g. 23: Coke, refined petroleum products and nuclear fuel) the effect is more pronounced than for industries producing more sophisticated goods (e.g. 30-33: Electrical and optical equipment). Trade is strongly increasing in country *j*'s population with an average elasticity of 0.540 and decreasing in both country *i*'s and country *j*'s area. The impact of country *i*'s population is insignificant or negative for most industries.

In line with previous studies we find that, all else being equal, landlocked countries trade considerably less (some 60 percent on average) and that a countries sharing a border trade more (some 140 percent). Finally, and most importantly, our regressions confirm that geographical variables are an important determinant of international trade. The average R^2 of our regressions is 0.471, ranging from 0.228 to 0.550.

3) Implications for Aggregate Trade and the Quality of the Instrument

Our instrument Z_{ik}^{Trade} must fulfil two properties. First, it must be uncorrelated with the error term in (2). Since our models are exactly identified so that we cannot test for overidentifying restrictions, this assumption has to be made on theoretical grounds: In our most general setting, i.e. model 2(c), this requires that geography has no direct effect on productivity, once country-specific effects (such as country size and quality of institutions) are controlled for. Second, the instrument must also be relevant, since two stages least squares with weak instruments may yield strongly biased estimates and tests with large size distortions (Staiger and Stock, 1997; Stock, Wright, and Yogo, 2002). Hence, it will be important to check the quality of the instrument.

The correlation between *Trade* and Z^{Trade} amounts to 0.753 for the export ratio (0.579 for *m* and 0.755 for *mx*). However, our constructed trade share is useful only insofar, as it contains information about the endogenous variable (the trade share) that goes beyond that contained in the control variables (industry-specific effects, *L, Pop, Area* and country-specific effects). To put it differently: What is relevant is the strength of the partial correlation between the actual and the constructed trade share.

Stock and Yogo (2004) work out a definition of weak instruments (based on bias and size distortion) and develop a test for weak instruments. For our case of one endogenous regressor, the test statistic amounts to the F-statistic on excluding the instrument in the first stage regression.

< Table 2 here >

Table 2 shows the results of the first stage regressions for the cross-section models (2a), (2b), and (2c).The F-test of the excluding restriction for the constructed trade shares generally exceed the critical values by Stock and Yogo (2004) that instrument quality is below the highest quality level.[7] Nevertheless, the predictive power is much stronger for exports and exports plus imports than for the import ratio. This is also true when a heteroscedasticity-robust variant of the Stock and Yogo test is used.[8]

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[7] For exactly identified models, Stock and Yogo provide only critical values for the size criterion (16.38, 8.96, 6.66, and 5.53 for the four quality levels).

[8] The results by Stock and Yogo (2004) are based on the assumption of homoscedasticity and have not yet been extended to more general cases. Hence, the critical values may only be regarded as indicative for the robust F-test.

IV. Trade and Productivity: Estimation Results

1) Estimation for Manufacturing Industries

Having constructed the instrument and verified its quality we now turn to the estimation of trade's effect on productivity. We start with the most parsimonious specification, i.e. equation (2a) and give the results for all three trade measures used. Results are given in Table 3. The IV estimates tell the same story for all three measures: Trade turns out to be a statistically and economically significant determinant of productivity.[9] The elasticities implied by the coefficients (when evaluated at the sample mean) are identical for the export ratio and the ratio of exports plus imports to production (0.15), slightly higher for imports (0.22).

< Table 3 here >

It is interesting to consider the bias of the least squares estimates. Highly productive industries tend to export more due to comparative advantage; in contrast, high productivity in domestic industries may keep away imports. As a result one would expect the least squares estimates of the export ratio to be upward biased, that of the import ratio to be downward biased. As previous studies emphasized, this endogeneity resulting from omitted variables and simultaneity is likely to be meshed up with a bias due to measurement error, since trade is a noisy measure for international transactions and openness; this would bias the least squares estimates towards zero. In fact, a comparison of the least squares and IV-estimates suggests that our results are in line with these theoretical presumptions.

We now turn to the estimation of model (2b), which controls for country size, and model (2c), which includes country dummies and thus controls for all country-specific effects

[9] For inference, we use heteroscedasticity-robust standard errors, which is clearly important in our cross-country and cross-industry sample. But (in contrast to Frankel and Romer) we do not correct the standard errors to account for the fact that Z^{Trade} is generated from the gravity model, since the asymptotic distribution of the test-statistics is not affected by the use of a generated instrument (see Wooldridge, 2002).

including institutional quality. Table 4 shows the IV results for models (2b) and (2c) using the three alternative trade measures.

< Table 4 here >

Turning to the results for model (2b) first, we find that the estimated effect of trade on productivity remains statistically significant and increases in magnitude to roughly twice the value of model (2a). Since country size tends to be positively related to productivity but negatively related to openness this results is not too surprising. The coefficients of the two size measures, however, are less easy to interpret. Area has a positive effect and is significant in two of the three models; population has the wrong (negative) sign, though it is only significant in two models at the five and ten percent level respectively. The negative sign of population appears to be largely driven by its correlation with the industry-specific size measure (L_{ik}); if L_{ik} is omitted, the effect of population becomes positive and significant throughout, and the effect of trade on productivity becomes smaller (though it still remains higher than in model (2a)).

For our most general model (2c), which is also our preferred specification, we observe that the results are robust for the export ratio but not for the models using the two other trade measures, where the effect of trade on productivity becomes insignificant. The most likely explanation for this discrepancy is that instrument quality is much higher for exports than for imports, particularly in model (2c); as a result the IV estimates for imports cannot eliminate the strong bias of the parameter estimate which remains negative for imports. Using imports plus exports imposes the same coefficient for exports and imports, which implies an averaging towards zero, a tendency that is likely to be enforced for the least squares estimates by measurement errors.

Focussing on the results for exports we find that the results of model (2a) are largely confirmed. Controlling for country size alone (model (2b)) increases the estimated effect, since country size is positively related to productivity but negatively to openness; controlling for institutional quality using country dummies (model (2c)) reduces the effect again, since institutional quality is positively related to productivity and trade. After all, the elasticity of productivity with respect to trade turns out to be 0.156 for the export ratio, de facto the same as for model (2a). While our results confirm that omitting institutional quality is relevant for the results, we still find a genuine effect of trade on productivity once institutions are controlled for. This is a vindication of the Frankel and Romer results and a qualification to the relevance of the Rodriguez-Rodrik critique.

2) Estimation for Aggregate Manufacturing

As already mentioned above, the industry specific specification captures only effects of trade in industry *k* on productivity in industry *k*, but does not capture effects that materialize across industries (inter-industry spillovers) such as reallocations to more productive industries, spezialization according to comparative advantage, and external economies of scale of inter-industry type as described by Balassa (1961).

To assess the relevance of these inter-industry spillovers, we turn to an estimation of model (2) at the aggregate level. To ensure comparability of the results we use the same fourteen countries, the same time period (averages over the period 1995 to 2000), the same base year 1995 for prices and PPPs. Instead of sub-industries of manufacturing, however, we use aggregate manufacturing data which ensures that inter-industry effects are also captured by the regression. Accordingly, the instrument is now constructed from the geographical gravity equation estimated using bilateral trade in total manufacturing (see Table 1 for the results).[10]

[10] For reasons of better and more consistent data we use trade in goods (manufacturing, agriculture, mining and quarrying) as explanatory variable in the aggregate models (5). Since manufacturing is by far the most important component of trade in goods this hardly matters for the results.

In our disaggregated specification there was already high correlation between country size and industry size (some 0.80). At the aggregate level this multicollinearity becomes even more pronounced (with a correlation of 0.98), so that we decided to drop one of the two variables. To ensure better comparability with previous studies we decided to drop industry size from the sample, but it can be imagined from the high correlation that this choice is not crucial. Consequently, the aggregate version of model (2b) is

$$\ln y_{iM} = a + b_1 Trade_{iM} + b_2 \ln Pop_i + b_3 \ln Area_i + e_i \,, \tag{5b}$$

and model (2c) becomes

$$\ln y_{iM} = a_i + b_1 Trade_{iM} + b_2 Pop_i + b_3 \ln Area_i + e_i \,. \tag{5c}$$

The index M indicates that the variables are measured at the aggregate manufacturing level. In contrast to model (5b) where the only problem is the small number of observations, model (5c) cannot be estimated since the number of parameters would exceed the number of observations. We can however, eliminate the country-specific effects (a_i) and estimate b_1 and b_2 using a first differenced variant of model (5c):

$$\Delta \ln y_{iM} = b_1 \Delta Trade_{iM} + b_2 \Delta \ln Pop_i + \Delta e_i \,. \tag{5c'}$$

The time invariant variable *Area* is also eliminated by this transformation. Instead of averages over the period 1995 to 2000, now differences between the year 1995 and 2000 are used. A larger time span for the difference would be desirable, but this is ruled out by data availability. In addition, the choice of the same time period as for the industry specific model ensures the comparability of the results.

Of course, endogeneity of trade is an issue at the aggregate manufacturing level as well. Again this is addressed using the geographical trade share as instrument (Z_{iM}^{Trade}), which is now calculated from the results of a (bilateral) geographical gravity model at the aggregate manufacturing level.

A note on model (5c') is in order here. The geographical trade share, an aggregate measure of proximity, is a time invariant variable (at least over short periods such as ours); hence, we cannot use its difference as instrument. But there is nothing that prevents us from using Z_M^{Trade} in levels as instrument for the first differences of the trade variable ($\Delta Trade^M$).[11]

Table 5 shows the estimates of (5b) and (5c') at the aggregate manufacturing level, again for all three trade measures. Instrument quality is fine for model (5c') as indicated by the F-tests at the bottom of the Table, which always exceed the critical values from Stock and Yogo (2004). Instrument quality is less favourable for model (5b); while we can still reject the hypothesis that instrument quality is below the second lowest quality level, results should be interpreted with caution. Hence, also from an econometric perspective, our preferred model is (5c'), which is more appealing from a theoretical perspective as well since it accounts for potential cross-country heterogeneity (e.g. in the quality of institutions).

< Table 5 here >

Overall, trade again has a significant effect on productivity, now irrespective of the measure used. As at the industry level, controlling for institutions in addition to country size (5c') the effect becomes smaller but remains statistically and economically significant. And as expected, the coefficient of trade is clearly larger in the aggregate model (5) than in the industry-specific specification (3). The elasticity of productivity with respect to openness is some 0.6. This suggests that propagation mechanisms are important, more important than the direct effect of trade within the same industry. For completeness, we also add that the exclusion of population (L, ΔL) hardly matters for the results.

One could object that the results are unreliable due to the small number of observations. To check the robustness, we use a panel variant of model (5), again over the period 1995 to

[11] In fact, this is a standard approach in many GMM applications, e.g. the GMM estimator in first differences by Arellano and Bond (1991).

2000. This means for model (5b) the annual levels are used instead of the averages over the period 1995 to 2000, and for model (5c') annual differences. For both models this yields a time dimension of six years.

The instrument Z_M^{Trade} is time invariant; this implies that the identifying variation is still the one across countries rather than over time, but this causes no problem here: Our goal is not to account for additional heterogeneity across countries or over time but to add degrees of freedom. Hence, both the first and second stage regressions for models (5b) and (5c') are carried out in a pooled fashion, i.e. with homogenous parameters across countries.

< Table 6 here >

Table 6 shows the results. The panel regressions confirm the results from the simple cross section estimation; the effects are even slightly larger.

3) Estimation for Aggregate Services

Of course, it would be desirable to carry out the same analysis using a sample of service industries. Unfortunately, industry-specific estimates cannot be carried out in the framework of our model since there is no data on bilateral trade in services at a disaggregated level, which would be required to construct industry-specific instruments.[12]

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[12] We tried to get some tentative results, carrying out least squares estimates of models (2) using a sample of 11 countries and 13 service industries (construction; trade and repair; travel; water/land transport; air transport; post and telecommunications; financial intermediation; insurance and pension funding; renting of machinery and equipment; computer and related activities; research and development; real estate activities; other business activities). Results were disappointing (also for subsamples of industries): The trade variable always turned out insignificant and/or showed the wrong sign. Besides the well known problems with data quality for services, a possible explanation is that services are much more inter-twined than manufacturing industries, making the industry-specific specification less suitable. The detailed results are omitted for brevity but are available upon request.

What we can do however, is to parallel the analysis for aggregate manufacturing and estimate the productivity effects of trade in services at the aggregate service level. That is, we use the same model (5), but now using data on aggregate services rather than manufacturing. Overall, results turn out much worse than for manufacturing (in statistical terms). Results for the model in levels are extremely sensitive to small changes in the sample and specification and yielded highly implausible estimates for the parameter of *Trade*. Results for model (5c) in first differences gave more reasonable results; the cross section and panel estimates for the three trade measures are given in Table 7.

< Table 7 here >

Results for model (5c') have to be treated with caution as well since the quality of the instrument (Z_{iS}^{Trade}), constructed from geographical gravity model based on bilateral trade in total services) is less favourable. The largest F-statistics is 4.99 (cross section model for exports), which implies that even for this model we cannot reject the hypothesis that instrument quality is below the lowest level. The elasticities turn out to be 0.073 in the cross section estimates; in the panel estimates they are roughly twice as large (0.153), but instrument quality is even lower in the panel models, so that we focus on the cross sections results.

The implied elasticities around 0.1 are clearly lower than in manufacturing (some 0.6). In judging the size of the effect, however, it has to be borne in mind that traded services are de facto only business services, but the value added per worker measure is based on total services, of which only 40 percent are business services. Assuming that non-commercial services are not affected by service trade and rescaling the estimate accordingly, the elasticity of productivity in business services with respect to service trade turns out to be 0.17. This is still much smaller than for manufacturing, but in light of the large standard errors this discrepancy to manufacturing should not be overstressed.

4) Estimation for Total Economy

As a final step, we carry the analysis one step further, regressing GDP per worker on total trade, i.e. trade in goods and services. This most aggregate specification ensures that we capture not only spillovers within the manufacturing industry (and within services) but also between manufacturing and services. Following the logic of our previous models, trade in goods and services is now expressed as share of GDP. Thus, ultimately we arrive at a specification which is comparable with the Frankel and Romer (1999) model:[13]

$$\ln y_i = a + b_1 Trade_i + b_2 \ln Pop_i + b_3 \ln Area_i + e_i \, . \tag{6b}$$

Model (5c') becomes

$$\Delta \ln y_i = b_1 \Delta Trade_i + b_2 \Delta \ln Pop_i + \Delta e_i \, . \tag{6c'}$$

Tables 8 gives the cross-section results for models (6b) and (6c'); Table 9 presents the panel estimates. Again the IV estimates use the geographical trade share as instrument (Z_i^{Trade}), which we calculate as (production-share) weighted sum of the geographical shares of trade in goods (Z_{iM}^{Trade}) and trade in services (Z_{iS}^{Trade}). Instrument quality is fine in the cross-section models and satisfactory in the panel models. Result are robust for all cross-section and panel models: Trade has a significant effect on productivity, irrespective of the trade measure used. The elasticities of productivity with respect to trade are around 0.20. This is in line with the average results of 0.22 obtained in many previous studies according to the survey by Lewer and Van den Berg (2003).

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[13] The remaining difference in the specification is that Frankel and Romer use trade in goods only and employment instead of population. The sample differs with respect to the time period (1986 versus averages of the period 1995 to 2000) and the countries included (150 countries versus 14 OECD countries).

< Table 8 here >

< Table 9 here >

5) Comparing the Magnitude of the Estimated Effects at Different Levels of Aggregation

Table 10 highlights once more the differences in the elasticities implied by the estimation results at different levels of aggregation. The values are based on the cross section estimates of model (2c) and the aggregate models in first differences (c').

< Table 10 >

There are several results worth mentioning: The effect of trade on productivity in manufacturing is much higher when estimated at a more aggregate level. This suggests that general equilibrium effects and inter-industry spillovers, which are not captured in a disaggregated specification, are important. In our setting, they are actually more important than intra-industry effects: some three quarters of the total effect appear to be of inter-industry type, but of course the exact relation will depend on the level of disaggregation chosen.

Comparing the aggregate estimates for manufacturing and services, we find that the effect is smaller in services, even if only business services are considered. As already mentioned above the results for services have to be treated with caution, but this may suggest that the productivity gains from service liberalization are smaller than the ones realized by the integration of goods markets, at least for the channel considered in this paper.

Another striking result is that the total effect obtained from the separate estimates for manufacturing and services (calculated using a (value-added share) weighted average of the tow values) is de facto equal to that obtained in the aggregate estimates using trade in goods and services. This suggests that inter-industry spillovers are important within manufacturing (and presumably within services as well), but that there are hardly spillover effects from goods to services sectors, at least as far as the productivity effects of trade are concerned.

Considering the elasticity from the aggregate estimation of around 0.2, it is smaller than that of previous studies, which use a similar setting. The average elasticity implied by the estimates of Frankel and Romer (1999) is 1.8; their lower bound elasticity amounts to around 0.5. Alcalá and Ciccone (2004), who control for institutional quality and use the log of real openness, obtain elasticities between 0.91 and 1.49 (and, similarly, elasticities around one if nominal openness is used). There are two likely explanations for this result:

First, the effect of trade on productivity in previous studies could be biased upwards. Most studies use aggregate productivity but trade in goods as explanatory variable. Services make up more than two third of GDP and trade in services has risen considerably over the last years. Since trade in goods is likely to be highly correlated with trade in services, the coefficient could also capture productivity effects of trade in services. For studies, which use many developing countries (where service trade is negligible) or use time periods where services have been less important (such as 1985 in the Frankel and Romer paper), this is an unlikely explanation, however.

Second, the discrepancy could be due to the sample choice. If there are decreasing returns to economic (trade) integration, the small effect of our estimates could be due to the fact that ours sample consists of highly integrated countries with comparably large trade shares. Trade may have a larger effect on productivity if a country is more distant from the technology frontier, since trade facilitates the catching-up process by transmitting technological know-how. This effect diminishes as countries move closer to the technology frontier.[14]

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[14] We also reproduced the Frankel and Romer (1999) estimates using their data and checked whether the coefficient of trade is significantly different for our subsample (by including a dummy for our 14 countries and an interaction of the trade share with that dummy). While the deviation is in fact negative, implying a

V. Summary and Conclusions

This paper adds to previous studies on the effects of trade on productivity, providing an analysis at both the aggregate level and the manufacturing industry-level for a sample of 14 OECD countries. To deal with endogeneity concerns, we follow the approach by Frankel and Romer (1999) and use the geographical component of (industry) trade as instrument.

The approach pursued here has two main advantages: The use of industry-data allows us to control for country-specific fixed effects such as the quality of institutions, avoiding the delicate issue of constructing a convincing measure for the institutional quality. Second, relating industry-specific productivity to industry-specific trade narrows the hypothesis of the aggregate specification chosen in previous studies by ruling out productivity effects of trade that materialize across industries. Comparing these results with that obtained using more aggregate data from the same sample allows us to judge the relevance of the particular channels via which trade affects productivity, a point hardly addressed in previous studies.

There are several interesting results: First, trade turns out to be a significant determinant of productivity, even if institutions are controlled for. In manufacturing, inter-industry effects turn out even more important than intra-industry effects, accounting for some three quarters of the total effect. We can confirm this finding at the aggregate level for services, though the magnitude of the effect is clearly smaller. We also find that spillovers between goods and services appear to be negligible.

The aggregate estimates suggest that an increase in openness by one percent raises productivity by 0.2 percent. This is economically significant but lower than the elasticity obtained in previous studies. The two most likely explanations are an upward bias in previous

substantially lower effect of trade on productivity for our sample, the difference is insignificant. In light of the fact that the estimates are rather imprecise, the results are somewhat inconclusive.

studies as a result of omitting trade in services as well as the existence of decreasing returns to trade integration.

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Appendix

Data description

All data are averages over the period 1995-2000. Cross-country dimension i comprises 14 countries (AUT, BEL, DEU, DNK, ESP, FIN, FRA, GBR, GRC, ITA, NLD, NOR, SWE, USA); dimension of partner countries j ($j \neq i$) comprises the 223 countries contained in the CEPII dataset; for the estimation of the gravity equation (8) the dimension j reduces to the 44 partner countries ($j \neq i$) for which bilateral trade data by industry are available; for services the number of observations is smaller due to missing data. Industry dimension k comprises the 15 manufacturing industries shown in Table A1. In addition, some models are estimated for total manufacturing ($k = M$), total services ($k = S$), as well as goods and services ($k = GS$).

$Trade_{ik}^{j}$ trade share; $Trade_{ik}^{j} = T_{ik}^{j} / PROD_{ik}$, where T_{ik}^{j} is bilateral trade between country i and country j in sector k and $PROD_{ik}$ is the production of country i in sector k. As measures for trade (T), imports (M), exports (X), as well as imports plus exports (MX) are used. Source: OECD Structural Analysis (STAN) Database.

y_{ik} labour productivity; $y_{ik} = VA_{i}^{k} / L_{ik}$, where VA_{i}^{k} is real valued added of country i in sector k in 1995$ (base year 1995, converted into $ with average PPPs exchange rate over the period 1995-2000) and L_{ik} is total employment in industry k of country i. Source: OECD Structural Analysis (STAN) Database.

$Dist_{ij}$ simple distance between country i and country j. Source: CEPII (Clair et al., 2004).

Pop_{i} population of country i in 1000 persons. Source: United Nations: Demographic Yearbook.

$Area_i$ area of country i in square kilometres. Source: CEPII (Clair et al., 2004).

LL_i dummy variable taking a value of one if country i is landlocked and zero otherwise. Source: CEPII (Clair et al., 2004).

CB_{ij} dummy variable taking a value of one if countries i and j share a border. Source: CEPII (Clair et al., 2004).

< Table A1 here >

Table A1. *Overview of Manufacturing Industries*

ISIC Rev3	industry	share in value added[1)]
15-16	Food products, beverages and tobacco	13.47
17-19	Textiles, textile products, leather and footwear	5.76
20	Wood and products of wood and cork	2.87
21-22	Pulp, paper, paper products, printing and publishing	11.15
23	Coke, refined petroleum products and nuclear fuel	2.11
24	Chemicals and chemical products	10.07
25	Rubber and plastics products	3.86
26	Other non-metallic mineral products	4.62
27	Basic metals	4.53
28	Fabricated metal products, except machinery and equipment	7.87
29	Machinery and equipment, n.e.c.	9.51
30-33	Electrical and optical equipment	11.28
34	Motor vehicles, trailers and semi-trailers	5.54
35	Other transport equipment	3.17
36-37	Manufacturing nec	4.34

Notes: [1)] Share in total manufacturing value added in percent. [2)] Ratio of exports to production in percent. All values are averages of the period 1995-2000 and the 14 countries.

Table 1. *Geography and Bilateral Trade: Estimation Results for Model (3) by Industry*

Dependent variable: $\ln x_{ik}^{j}$

Industry	15-16	17-19	20	21-22	23	24	25	26	27
Constant	4.563***	6.650***	4.771***	1.272	1.865	2.112***	5.066***	-1.578	2.311**
	(5.376)	(7.278)	(4.194)	(1.342)	(1.317)	(2.815)	(6.271)	(-1.833)	(2.461)
ln *Dist*	-0.835***	-1.186***	-1.100***	-0.903***	-1.327***	-0.762***	-1.016***	-0.793***	-1.000***
	(-14.221)	(-18.771)	(-13.958)	(-13.779)	(-13.185)	(-14.351)	(-18.181)	(-13.318)	(-15.386)
$\ln Pop_i$	0.064	0.070	-0.154	-0.255***	0.267**	0.013	-0.017	0.214***	-0.051
	(1.041)	(1.059)	(-1.865)	(-3.713)	(2.261)	(0.213)	(-0.282)	(3.432)	(-0.752)
$\ln Area_i$	-0.376***	-0.253***	-0.070	0.087	-0.072	-0.223***	-0.231***	-0.068	-0.115
	(-5.923)	(-3.707)	(-0.819)	(1.229)	(-0.633)	(-3.721)	(-3.831)	(-1.053)	(-1.636)
$\ln Pop_j$	0.425***	0.466***	0.493***	0.518***	0.533***	0.624***	0.426***	0.536***	0.728***
	(9.511)	(9.682)	(8.192)	(10.384)	(6.962)	(15.404)	(10.008)	(11.800)	(14.716)
$\ln Area_j$	-0.039	-0.063	-0.131***	-0.011	-0.122**	-0.061	0.012	-0.078**	-0.095**
	(-1.133)	(-1.685)	(-2.804)	(-0.279)	(-2.043)	(-1.939)	(0.366)	(-2.216)	(-2.476)
LL	-0.822***	-0.619***	-0.441***	-0.298**	-1.635***	-0.456***	-0.477***	-0.591***	-0.794***
	(-6.869)	(-4.803)	(-2.751)	(-2.231)	(-8.051)	(-4.240)	(-4.188)	(-4.870)	(-5.997)
CB	1.472***	1.002***	1.679***	1.426***	1.836***	1.184***	1.335***	1.526***	1.400***
	(5.914)	(3.741)	(5.041)	(5.132)	(4.346)	(5.281)	(5.637)	(6.050)	(5.082)
SE	1.367	1.472	1.829	1.527	2.247	1.194	1.302	1.386	1.513
R^2	0.478	0.511	0.404	0.435	0.416	0.550	0.535	0.457	0.519
Obs	616	616	611	616	567	572	616	615	616

Table 1 (continued). *Geography and Bilateral Trade: Estimation Results for Model (8) by Industry*

Dependent variable: $\ln x_{ik}^{j}$

Industry	28	29	30-33	34	35	36-37	manufacturing	services
Constant	1.979**	0.484	2.630***	5.180***	-2.430*	1.560	2.122***	-4.607***
	(2.583)	(0.707)	(3.348)	(5.329)	(-1.943)	(1.560)	(3.005)	(-3.993)
ln *Dist*	-0.847***	-0.579***	-0.683***	-1.028***	-0.425***	-0.864***	-0.734***	-0.609***
	(-15.980)	(-12.211)	(-12.578)	(-15.285)	(-4.916)	(-12.495)	(-15.023)	(-7.711)
ln Pop_i	-0.139**	0.013	-0.122**	-0.160**	0.183**	0.145**	-0.110**	-0.065
	(-2.497)	(0.270)	(-2.139)	(-2.276)	(2.016)	(2.000)	(-2.150)	(-0.771)
ln $Area_i$	-0.070	-0.190***	-0.113	-0.149**	-0.163	-0.150**	-0.088*	-0.137
	(-1.219)	(-3.700)	(-1.925)	(-2.046)	(-1.748)	(-2.011)	(-1.674)	(-1.588)
ln Pop_j	0.522***	0.604***	0.662***	0.499***	0.585***	0.472***	0.588***	0.468***
	(12.933)	(16.726)	(16.001)	(9.750)	(8.875)	(8.956)	(24.908)	(12.933)
ln $Area_j$	-0.031	-0.039	-0.154***	0.016	-0.124**	-0.082**	-0.094***	-0.029
	(-0.988)	(-1.402)	(-4.806)	(0.403)	(-2.433)	(-2.005)	(-3.267)	(-0.640)
LL	-0.581***	-0.449***	-0.497***	-0.783***	-0.066	-0.340**	-0.550***	-0.145
	(-5.376)	(-4.647)	(-4.484)	(-5.708)	(-0.372)	(-2.408)	(-5.523)	(-0.820)
CB	1.556***	1.273***	1.076***	1.205***	1.721***	1.522***	1.250***	1.247***
	(6.928)	(6.339)	(4.673)	(4.228)	(4.696)	(5.194)	(6.037)	(3.945)
SE	1.234	1.103	1.266	1.566	2.012	1.610	1.137	1.629
R^2	0.536	0.547	0.480	0.464	0.228	0.381	0.537	0.290
Obs	616	616	616	616	613	616	616	483

Notes: t-values in parenthesis . ***, **, * indicate significance at the 1, 5, and 10 percent level, respectively; *x* … export ratio.

Table 2. *Quality of Instrument: The Relevance of Geography for (Aggregate) Industry Trade, First Stage Regressions for Models (2a), (2b), and (2c)*

Dependent variable: $Trade_{ik}$

	Exports			Imports			Exports plus imports		
	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
$D^{Industry}$	yes	yes	yes	yes	yes	yes	yes	yes	yes
$D^{Country}$	no	no	yes	no	no	yes	no	no	yes
Z_{ik}^{Trade}	0.924***	0.900***	0.877***	0.854***	0.771***	0.891***	0.930***	0.938***	1.081***
	(11.829)	(8.502)	(6.713)	(4.627)	(4.444)	(4.409)	(10.082)	(9.119)	(8.067)
$\ln L_{ik}$	-0.059***	-0.022	-0.051*	-0.183***	-0.647***	-0.619***	-0.202***	-0.620***	-0.620***
	(-5.681)	(-0.730)	(-1.858)	(-7.879)	(-12.140)	(-11.546)	(-7.911)	(-10.074)	(-9.900)
$\ln Pop_i$	-	-0.039	-	-	0.536***	-	-	0.473***	-
	-	(-1.089)	-	-	(8.925)	-	-	(6.779)	-
$\ln Area_i$	-	-0.007	-	-	-0.007	-	-	0.016	-
	-	(-0.372)	-	-	(-0.262)	-	-	(0.474)	-
F-Stat.[1)]	139.92	72.29	45.06	21.41	19.75	19.44	101.65	83.15	65.08
F-Stat.[2)]	84.23	54.19	23.34	17.60	12.14	14.38	50.77	35.18	25.11
SE	0.186	0.186	0.161	0.392	0.322	0.310	0.422	0.370	0.358
R^2	0.704	0.707	0.794	0.621	0.748	0.781	0.773	0.828	0.849
Obs [3)]	193	193	193	193	193	193	193	193	193

Notes: t-values in parenthesis; ***, **, * indicate significance at the 1, 5, and 10 percent level, respectively. [1)] F-Test on excluding instrument from first stage regression, based on conventional standard errors. [2)] F-Test on excluding instrument from first stage regression, based on heteroscedasticity robust standard errors. [3)] Of the total 14x15=210 observations, 13 observations were missing (NOR: 23, 24; BEL: 27, 28, 34, 35; GBR: 27, 28, 34, 35; USA: 29, 30-33; NLD: 34, 35); 3 further observations turned out as outliers (AUT: 23; ESP: 23; GRC: 34), i.e. standardized residuals were larger than three in de facto all models, such that 193 observations remain. This sample is used throughout in the estimation.

Table 3. *Trade and Productivity: Least Squares and IV Results for Cross-Section Model (2a)*

Dependent variable is ln y_{ik}

	Exports		Imports		Imports plus exports	
	LS	IV	LS	IV	LS	IV
$D^{Industry}$	yes	yes	yes	yes	yes	yes
$D^{Country}$	no	no	no	no	no	no
$Trade_{ik}$	0.409***	0.334***	-0.079*	0.385**	0.042	0.153**
	(4.056)	(3.306)	(-1.783)	(2.061)	(1.082)	(2.382)
ln L_{ik}	0.101***	0.094***	0.047***	0.151***	0.078***	0.113***
	(6.404)	(6.266)	(2.952)	(3.075)	(4.711)	(4.513)
SE	0.230	0.230	0.249	0.315	0.250	0.257
R^2	0.750	-	0.706	-	0.704	-
Obs	193	193	193	193	193	193

Notes: t-values in parenthesis based on robust standard errors; ***, **, * indicate significance at the 1, 5, and 10 percent level, respectively.

Table 4. *Trade and Productivity: IV Results for Cross-Section Models (2b) and (2c)*

Dependent variable is ln y_{ik}	Exports		Imports		Imports plus exports	
	(2b)	(2c)	(2b)	(2c)	(2b)	(2c)
$D^{Industry}$	yes	yes	yes	yes	yes	yes
$D^{Country}$	no	yes	no	yes	no	yes
$Trade_{ik}$	0.709***	0.356**	0.611**	-0.089	0.278***	0.022
	(5.077)	(2.288)	(2.168)	(-0.720)	(3.109)	(0.395)
ln L_i	0.097**	0.052	0.481**	-0.036	0.265***	0.041
	(2.406)	(1.461)	(2.102)	(-0.377)	(2.822)	(0.734)
ln Pop_i	-0.029	-	-0.357*	-	-0.173**	-
	(-0.669)	-	(-1.793)	-	(-2.015)	-
ln $Area_i$	0.088***	-	0.049	-	0.058**	-
	(4.251)	-	(1.640)	-	(2.594)	-
SE	0.224	0.177	0.352	0.170	0.268	0.174
Obs	193	193	193	193	193	193

Notes: t-values in parenthesis based on robust standard errors; ***, **, * indicate significance at the 1, 5, and 10 percent level, respectively.

Table 5. *Trade and Productivity: IV Results for Cross-Section Models (5b) and (5c'), Aggregate Manufacturing*

Dependent variable is ln y_{iM}						
	Exports		Imports		Imports plus exports	
	(5b)	(5c') [3]	(5b)	(5c') [3]	(5b)	(5c') [3]
Constant	7.508***	-	5.477**	-	6.725***	-
	(10.279)	-	(2.778)	-	(8.331)	-
$Trade_{iM}$	1.374***	1.142**	2.501**	1.298**	0.904***	0.623**
	(3.633)	(2.610)	(2.782)	(2.809)	(4.355)	(2.662)
ln Pop_i	0.043	1.700	0.086	0.723	0.058	1.167
	(1.188)	(1.252)	(0.696)	(0.516)	(0.919)	(0.825)
ln $Area_i$	0.183***	-	0.271	-	0.218**	-
	(3.888)	-	(1.810)	-	(2.976)	-
F-Stat.[1]	4.997	22.177	4.242	20.362	9.233	29.142
F-Stat.[2]	9.603	43.450	7.664	58.205	8.948	58.797
SE	0.106	0.119	0.365	0.129	0.184	0.122
Obs	14	14	14	14	14	14

Notes: t-values in parenthesis based on robust standard errors; ***, **, * indicate significance at the 1, 5, and 10 percent level, respectively. [1] F-Test on excluding instrument from first stage regression, based on conventional standard errors. [2] F-Test on excluding instrument from first stage regression, based on heteroscedasticity robust standard errors. [3] Model (5c'): differences between 2000 and 1995 values of the variables.

Table 6. *Trade and Productivity: IV Results for Pooled Panel-Models (5b) and (5c'), Aggregate Manufacturing*

Dependent variable is ln y_{iM}						
	Exports		Imports		Imports plus exports	
	(5b)	(5c')[3]	(5b)	(5c')[3]	(5b)	(5c')[3]
Constant	7.463***	-	5.399***	-	6.695***	-
	(27.724)	-	(6.742)	-	(20.866)	-
$Trade_{iM}$	1.385***	1.534***	2.547***	1.591***	0.908***	0.795***
	(10.114)	(3.960)	(6.547)	(3.724)	(10.812)	(4.010)
ln Pop_i	0.052***	1.328*	0.084*	0.765	0.063**	0.996
	(3.740)	(1.712)	(1.754)	(0.828)	(2.559)	(1.250)
ln $Area_i$	0.179***	-	0.277***	-	0.216***	-
	(9.740)	-	(4.678)	-	(7.718)	-
F-Stat.[1]	35.950	8.419	24.767	4.597	55.631	7.771
F-Stat.[2]	50.873	4.386	33.053	4.104	44.065	4.529
SE	0.099	0.035	0.330	0.047	0.165	0.038
Obs	84	84	84	84	84	84

Notes: t-values in parenthesis based on robust standard errors; ***, **, * indicate significance at the 1, 5, and 10 percent level, respectively. [1] F-Test on excluding instrument from first stage regression, based on conventional standard errors. [2] F-Test on excluding instrument from first stage regression, based on heteroscedasticity robust standard errors. [3] Model (5c') in first (annual) differences.

Table 7. *Trade and Productivity: IV Results for Cross-Section and Panel Models (5c'), Aggregate Services*

Dependent variable is ln y_{iS}	Exports		Imports		Imports plus exports	
	Cross section	Panel	Cross section	Panel	Cross section	Panel
$Trade_{iS}$	0.855**	1.701**	0.944	1.835	0.356***	0.864**
	(2.297)	(2.586)	(1.775)	(1.602)	(3.265)	(2.097)
ln Pop_i	1.157***	0.747**	1.179	0.978	-0.308	0.874*
	(4.017)	(2.447)	(1.759)	(1.099)	(-0.442)	(1.721)
F-Stat.[1)]	2.022	0.308	0.406	0.062	0.792	0.198
F-Stat.[2)]	4.993	0.186	0.232	0.126	2.944	0.214
SE	0.039	0.017	0.071	0.048	0.071	0.028
Obs	14	84	14	84	14	84

Notes: t-values in parenthesis based on robust standard errors; ***, **, * indicate significance at the 1, 5, and 10 percent level, respectively. [1)] F-Test on excluding instrument from first stage regression, based on conventional standard errors. [2)] F-Test on excluding instrument from first stage regression, based on heteroscedasticity robust standard errors.

Table 8. *Trade and Productivity: IV Results for Cross-Section Models (6b) and (6c'), Aggregate Economy, Trade in Goods and Services*

Dependent variable is ln y_i

	Exports		Imports		Imports plus exports	
	(6b)	(6c') 3)	(6b)	(6c') 3)	(6b)	(6c') 3)
Constant	9.249***	-	9.266***	-	9.258***	-
	(19.720)	-	(18.118)	-	(21.000)	-
Trade	0.858**	0.612***	0.952**	0.660**	0.451***	0.329**
	(3.061)	(3.074)	(2.772)	(2.864)	(3.179)	(2.910)
ln *Pop*	0.036	1.168*	0.016	1.101	0.026	1.088
	(1.404)	(1.843)	(0.549)	(1.691)	(1.007)	(1.661)
ln *Area*	0.072**		0.086*		0.078**	
	(2.334)		(2.200)		(2.440)	
F-Stat. 1)	10.262	33.523	18.746	10.216	15.890	21.527
F-Stat. 2)	13.376	32.791	16.741	16.211	19.631	23.307
SE	0.091	0.050	0.000	0.053	0.000	0.050
Obs	14	14	14	14	14	14

Notes: t-values in parenthesis based on robust standard errors; ***, **, * indicate significance at the 1, 5, and 10 percent level, respectively. 1) F-Test on excluding instrument from first stage regression, based on conventional standard errors. 2) F-Test on excluding instrument from first stage regression, based on heteroscedasticity robust standard errors. 3) Model (6c'): differences between 2000 and 1995 values of the variables.

Table 9. *Trade and Productivity: IV Results for Pooled Panel-Models (6b) and (6c'), Aggregate Economy*

Dependent variable is ln y_i

	Exports		Imports		Imports plus exports	
	(6b)	(6c')[3]	(6b)	(6c')[3]	(6b)	(6c')[3]
Constant	9.248***	-	9.266***	-	9.257***	-
	(52.368)	-	(48.818)	-	(55.567)	-
Trade	0.859***	0.755***	0.952***	0.772***	0.451***	0.392***
	(8.137)	(4.283)	(7.378)	(3.942)	(8.390)	(4.126)
ln *Pop*	0.036***	0.792**	0.016	0.833**	0.027***	0.775**
	(3.787)	(2.045)	(1.480)	(2.051)	(2.726)	(2.009)
ln *Area*	0.072***	-	0.086***	-	0.078***	-
	(6.124)	-	(5.888)	-	(6.437)	-
F-Stat.[1]	113.738	7.554	113.738	7.247	104.542	8.369
F-Stat.[2]	99.222	5.145	88.559	3.725	103.904	4.021
SE	0.082	0.017	0.096	0.019	0.087	0.017
Obs	84	84	84	84	84	84

Notes: t-values in parenthesis based on robust standard errors; ***, **, * indicate significance at the 1, 5, and 10 percent level, respectively. [1] F-Test on excluding instrument from first stage regression, based on conventional standard errors. [2] F-Test on excluding instrument from first stage regression, based on heteroscedasticity robust standard errors. [3] Model (6c') in first (annual) differences.

Table 10. *Elasticities of Productivity with Respect to Trade implied by Estimates at Different Levels of Aggregation*

	Exports	Imports	Exports plus imports
Manufacturing industries	0.156	-	-
Aggregate manufacturing	0.601	0.659	0.642
Aggregate services	0.133	0.100	0.107
Total economy	0.204	0.207	0.212
Total economy[1)]	0.216	0.201	0.204

Elasticities calculated by evaluating derivatives at sample averages, using the cross-section estimates results for models (2c) and (c'). [1)] Sum of elasticities from aggregate services and aggregate manufacturing, weighted with share in value added.