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The effect of absorptive capacity on exports: a panel data analysis

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Abstract

In previous research, we analysed the effect of technological innovation, understood as absorptive capacity, on exports by using a gravity model of trade for the year 2000 (see Márquez-Ramos and Martínez-Zarzoso, 2010). We found that the effect of technological innovation on trade varies depending on technological achievement by generating a non-linear relationship between technological innovation and trade. A natural extension of this research is to use a panel dataset to fully account for unobserved country heterogeneity and to study the dynamics of the relationship between trade and technological innovation. In order to do so, in this paper, we construct a panel dataset including data for 65 countries over the period 1980-1999. To proxy for technological innovation, in Márquez-Ramos and Martínez-Zarzoso (2010) the different dimensions of technological achievement index (TAI) developed by UNDP (2001) were used. Instead, in the present paper the Human Development Index (HDI) is used as a proxy for absorptive capacity. Preliminary results point towards the existence of a non-linear relationship between technological innovation and international trade in a panel data framework.

JEL classification: F10

Keywords: Technological innovation, absorptive capacity, international trade, gravity model, panel data.

1. Introduction

International trade theory highlights the importance of technological innovation in explaining a country's international competitiveness (Posner, 1961, Vernon, 1966, Fagerberg, 1997).

At firm level, Cohen and Levinthal (1990) introduced the concept of absorptive capacity, which is the ability to recognise the value of new, external information, to assimilate it, and to apply it. These authors consider two faces of technological innovation: creation and absorption. In their model, some level of absorptive capacity is necessary to create, and the

cost of adoption increases as absorptive capacity falls. Hence, technological innovation is considered to reduce the cost of adoption. Zahra and George (2002) distinguished not only two subsets (potential and realised absorptive capacity), but also four dimensions of absorptive capacity: acquisition, assimilation, transformation and exploitation capabilities. Potential absorptive capacity consists of knowledge acquisition and assimilation, while realised absorptive capacity is made up of knowledge transformation and exploitation.

Recently, Márquez-Ramos and Martínez-Zarzoso (2010) have used the different components of the TAI index (UNDP, 2001) to analyse the effect of absorptive capacity on exports at a country level. These authors state that a greater potential absorptive capacity could be related to a higher level of technology creation and the spread of old innovations, whereas a greater realised potential absorptive capacity could be related to a greater spread of recent innovations and human skills. Additionally, they find that the relationship between the specific components of the TAI index and exports is non-linear. Creation of technology (knowledge acquisition) is associated with higher and increasing exports, whereas a "U-shaped" relationship is observed between the spread of old innovations (assimilation capability) and exports, and an inverted-U-shaped relationship is found between spread of recent innovations (knowledge transformation) and exports, and between human skills (knowledge exploitation) and exports.

Although the TAI has been used in a number of empirical analyses (Martínez-Zarzoso and Márquez-Ramos, 2005; Márquez-Ramos, 2007; Márquez-Ramos and Martínez-Zarzoso, 2010), a shortcoming of using this index is that it is available only for a single year. Indeed, using data for a cross-section of countries, we are not able to control for unobserved country heterogeneity, a very important concern when estimating the effect of technological advance on exports. Hence, we searched for an alternative measure that was available for developed and developing countries and could be used as a proxy for technological achievement. Arcelus, Sharma and Srinivasan (2005) support the proposition that technological achievement and human development indices show similar information and similar country rankings, thus questioning the need for the existence of two indices rather than one. In fact, only the human development index (HDI) has been computed over the years, whereas the TAI index is still today only available for 2000.

The main contribution of this paper is to estimate the effects of technological innovation improvements on bilateral exports in a panel data framework, thus controlling for unobserved country heterogeneity. To the best of our knowledge this is the first paper to do so at a macro level using a gravity model of trade. This sheds a new light on many interpretations of the

effect of innovation and questions the validity of previous estimates. Our results show that the elasticity of trade flows with respect to technological innovation remains large in the model and varies with the degree of technological advance in the countries.

The rest of paper is arranged as follows: Section 2 introduces the conceptual framework for analysing the dynamics of technological innovation. Section 3 describes data, presents the estimation strategy and the main results. A final section summarises the main findings.

2. The dynamics of technological innovation on exports

In this paper, we define technological innovation as a country's "absorption capacity" – the ability to put information from abroad into practice by developing new products and processes which play a key role in international trade and economic development.[1] Within this framework, we aim to provide empirical evidence on the relationship between technological innovation and international trade using panel data to fully account for unobserved country heterogeneity and to study the dynamics of the relationship between trade and technological innovation. In order to do so, we use the HDI to proxy for technological innovation.

A number of authors in the '60s focused on the timing of innovations and considered R&D investment and human skills as the main drivers of innovation (Posner, 1961; Vernon, 1966; Jones, 1970). Recently, Criscuolo and Narula (2008) showed that when countries move from the pre-catching-up and the catching-up stage to the pre-frontier-sharing and the technological frontier, the cumulative nature of the learning process and the increase complexity of external knowledge could result in a non-linear relationship between national absorptive capacity and exports. Once countries achieve a threshold level of absorptive capacity, absorption and catching-up processes may occur rapidly, and firms are able to compete in world markets. Márquez-Ramos and Martínez-Zarzoso (2010) hypothesise that developing countries may need a minimum technological innovation level to obtain trade gains derived from higher technological innovation achievements, whereas the technological innovation level already achieved in developed countries is sufficient to obtain trade gains from technological innovation developments. In fact, this authors state that the TAI allows countries to be classified into four groups according to their level of technological innovation and their stage of knowledge accession: Leaders are countries in the technological frontier-sharing stage, Potential Leaders are countries in the pre-frontier-sharing stage, Dynamic Adopters are countries in the catching-up stage and Marginalised countries are those in the pre-catching-up stage.

[1] For a review see Zahra and George (2002).

At a firm level, Yeh, Chu, Sher and Chiu (2010) prove that it is possible to identify a single-threshold effect. These authors use an advanced panel threshold regression model, pioneered by Hansen (1999), which makes it possible to determine the threshold level of technological innovation on firm performance. When a single threshold exists and technological innovation is lower than the threshold, a positive technological innovation coefficient signifies that further technological innovation can enhance firm performance. Otherwise, when technological innovation is greater than the threshold, a negative technological innovation coefficient signifies that increasing technological innovation is detrimental to firm performance.

In this paper, we suggest a dynamic non-linear technological innovation-trade performance relationship, as shown in Figure 1. Technological innovation is shown on the horizontal axis, and trade performance on the vertical axis. The diagram is divided into eight quadrants, with respect to the different possible combinations of technological innovation achievement and trade performance. In the horizontal axis, Quadrants I-II, III-IV, V-VI and VII-VIII represent those countries classified as Technologically Marginalised, Dynamic Technological Adopters, Potential Technological Leaders and Technological Leaders respectively, according to the TAI index (see Márquez-Ramos and Martínez-Zarzoso, 2010). In the vertical axis, Quadrants I, III, V and Quadrant VII represent countries with strong trade performance, whereas Quadrants II, IV, Quadrant VI and VIII represent countries with weak trade performance.

Figure 1. Technological innovation and trade performance

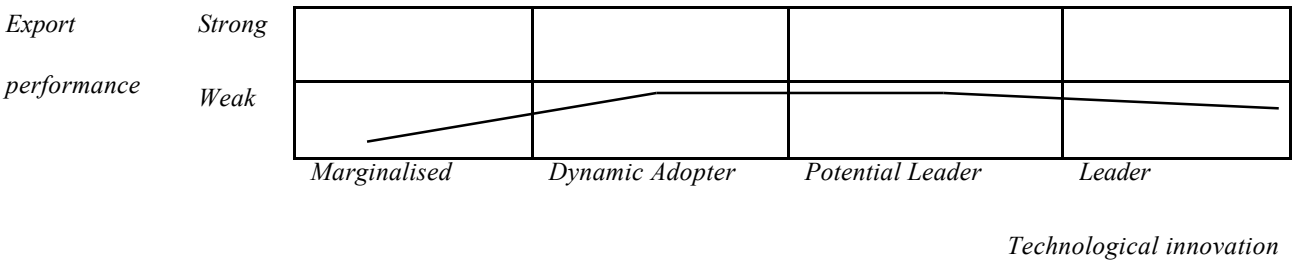
Export performance					
Strong	Quadrant I	Quadrant III	Quadrant V	Quadrant VII
Weak	Quadrant II	Quadrant IV	Quadrant VI	Quadrant VIII
	Marginalised	*Dynamic Adopter*	*Potential Leader*	*Leader*

Technological innovation

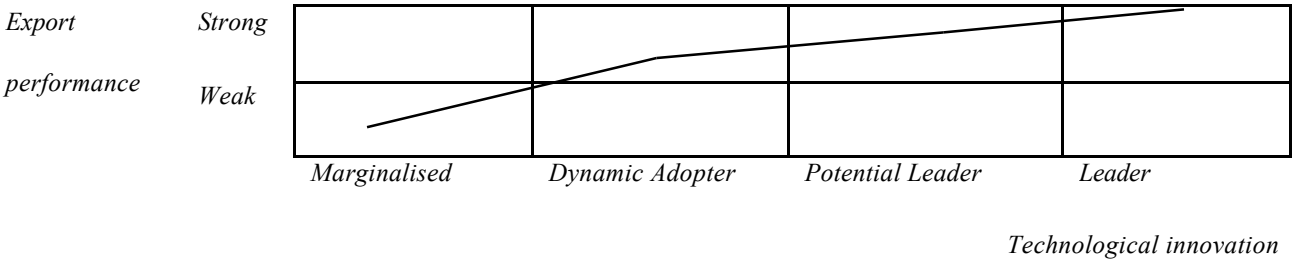
Following this diagram, a number of possible combinations of technological innovation and export performance can be hypothesised for different countries, as shown in Figure 2.

Figure 2. Technological innovation and trade performance: Country comparison

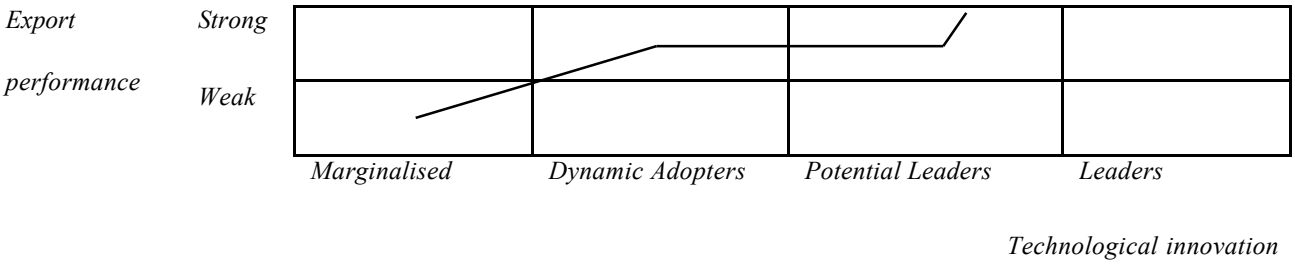
Country A



Country B



Country C



The hypothetical plot for Country A indicates an improvement in export performance in moving from a Marginalised to a Dynamic Adopter, followed by decreasing exports when the country reaches the Leader technological position. In the case of Country B, there is a clear improvement in trade performance in moving from a Marginalised to a Leader technological position, although the improvement is greater at the earlier stage of technological improvement. Finally, the graph for Country C indicates that this country does not reach the Leader stage, but technological innovation leads to an improvement in export performance in the early and in the latest stages of the process, where technological innovation seems to contribute to generate higher exports at different rates.

In the empirical analysis, we provide new evidence of the relationship between technological innovation and international trade and existing threshold levels of technological innovation at country level. It is very important to identify existing threshold levels of technological

innovation at country level, as absorptive capacity needs to be built in developing countries before they are able to profit from technological innovation improvements (Márquez-Ramos and Martínez-Zarzoso, 2010).

3. Empirical application and main results

3.1 Data, variables and model specification

We use data for 65 countries in the years 1980, 1985, 1990, 1995 and 1999 with a total of 4160 (65*64) bilateral trade flows each year (Appendix, Figure A.1). The presence of missing/zero values in the bilateral trade flow data for different years slightly reduces the sample (e.g. in 1999 there were 3347 observations). Summary statistics for the variables considered in the empirical analysis are presented in Table 1.

The estimated model is given by equation (1):

$$\begin{aligned}\ln X_{ijt} &= \delta_i + \alpha_1 \cdot \ln Y_{it} + \alpha_2 \cdot \ln Y_{jt} + \alpha_3 \cdot \ln YH_{it} + \alpha_4 \cdot \ln YH_{jt} + \alpha_5 \cdot Adj_{ij} + \alpha_6 \cdot Land_i + \\ &+ \alpha_7 \cdot Land_j + \alpha_8 \cdot RIA_{ijt} + \alpha_9 \cdot \ln Dist_{ij} + \alpha_{10} \cdot Lang_{ij} + \alpha_{11} \cdot HDI_{it} + \alpha_{12} \cdot HDI_{jt} + u_{ijt}\end{aligned} \quad (1)$$

where *ln* denotes natural logarithms.

X_{ijt} denotes the value of exports from the exporter country i to the importer country j in year t; Y_{it} and YH_{it} are income and income per capita in the exporter's market; Y_{jt} and YH_{jt} are income and income per capita in the destination market in year t; Adj_{ij} is a dummy that takes a value of 1 when countries share the same border and zero otherwise; $Land_i$ and $Land_j$ are dummies that take the value of 1 when the exporter and the importer are landlocked countries. We use a Regional Integration Agreement (RIA) variable as in Márquez-Ramos et al (2009), and then RIA is a dummy that takes a value of 0 when trading partners do not have a RIA. This variable takes a value of 1 when both exporter and importer have a Preferential Trade Agreement, 2 when both are members of the same Free Trade Agreement, 3 when both countries belong to the same Customs Union, 4 when both countries are in a Common Market and 5 both belong to the same Monetary Union. Since suitable direct measures of trade costs are unavailable, geographical distance between countries is often used as a proxy for transport costs in gravity equations. Thus, $Dist_{ij}$ is the geographical great circle distance in kilometres between the capitals of country *i* and *j*. $Lang_{ij}$ is a dummy for countries sharing the same language; this variable generally captures information costs in countries. HDI_i and HDI_j proxy for the effect of technological innovation.[2]

A number of additional explanations are needed with respect to technological variables. The HDI (UNDP, 2001) is used in this paper to measure technological innovation (Arcelus et al,

[2] Table A.1 in the Appendix shows a summary of the data used in our analysis.

2005). The HDI measures the average achievements in a country over three dimensions of human development: a long and healthy life, as measured by life expectancy at birth; knowledge, as measured by the adult literacy rate and the combined primary, secondary and tertiary gross enrolment ratio; and a decent standard of living, as measured by GDP per capita. Scores are derived as an index in relation to the maximum and minimum scores achieved by countries in any indicator of the three above-mentioned dimensions. The performance of each index takes a value of between 0 and 1, which is calculated according to equation (2).

$$HDI = \frac{(actual value - observed \min value)}{(observed \max value - observed \min value)} \qquad (2)$$

The HDI is calculated as a simple average of the three dimension indices, based on the assumption that components play a comparable role of a country's human development.

A second specification accounts for non-linearities of the HDI variables. A quadratic term is added for the exporter and for the importer HDI. The model is specified as,

$$\begin{aligned} \ln X_{ijt} &= \delta_i + \alpha_1 \cdot \ln Y_{it} + \alpha_2 \cdot \ln Y_{jt} + \alpha_3 \cdot \ln YH_{it} + \alpha_4 \cdot \ln YH_{jt} + \alpha_5 \cdot Adj_{ij} + \alpha_6 \cdot Land_i + \\ &+ \alpha_7 \cdot Land_j + \alpha_8 \cdot RIA_{ijt} + \alpha_9 \cdot \ln Dist_{ij} + \alpha_{10} \cdot Lang_{ij} + \alpha_{11} \cdot HDI_{it} + \alpha_{12} \cdot HDI_{jt} \\ &+ \alpha_{13} HDI_{it}^2 + \alpha_{14} HDI_{jt}^2 + u_{ijt} \end{aligned} \qquad (3)$$

where HDI_{it}^2 and HDI_{jt}^2 denote respectively the squared terms of the HDI indices.

Next, a dynamic model is estimated that adds the first lag of the dependent variable as an additional regressor. To account for unobservable heterogeneity and endogeneity of the lagged dependent variable the model is estimated in first differences and using instruments:

$$\begin{aligned} D\ln X_{ijt} &= \delta_i + \lambda DX_{i,t-1} + \alpha_1 \cdot D\ln Y_{it} + \alpha_2 \cdot D\ln Y_{jt} + \alpha_3 \cdot D\ln YH_{it} + \alpha_4 \cdot D\ln YH_{jt} + \alpha_5 \cdot Adj_{ij} + \\ &\alpha_6 \cdot Land_i + \alpha_7 \cdot Land_j + \alpha_8 \cdot RIA_{ijt} + \alpha_9 \cdot \ln Dist_{ij} + \alpha_{10} \cdot Lang_{ij} + \alpha_{11} \cdot DHDI_{it} + \alpha_{12} \cdot DHDI_{jt} \\ &+ \alpha_{13} DHDI_{it}^2 + \alpha_{14} DHDI_{jt}^2 + u_{ijt} \end{aligned} \qquad (4)$$

3.2 Main results

Table 2 shows the results of estimating equation (1) and (3). The model was first estimated by OLS and a Wald test confirms the presence of unobserved heterogeneity that could be modelled as being random or fixed. Columns (1) and (2) in Table 2 show the obtained estimates of equation (1) estimated by using a GLS and a Fixed-effects-within estimators. A Hausman test indicates that the random effects (re) estimates are inconsistent and we therefore rely on the fixed effects (fe) estimates. The exporter's HDI coefficient is statistically significant and shows the expected positive sign. The magnitude indicates that a ten

percentage-point increase in HDI increases exports by around 34 percent. Column (3) in Table 2 shows the results of the within fixed effects estimator when the squared terms for HDI are added. The results indicate the existence of an inverted U-shaped relationship between exports and HDI of the exporter. Exports increase with HDI of the exporter up to a point (HDI = 0.79) and then decrease. Finally, column (4) in Table 2 estimates the model using a generalised linear model (GLM) with the dependent variable in levels, to take also into account zero values of the dependent variable. The estimator is a fixed-effect Poisson with robust standard errors. We obtain a similar relationship, with the only difference that the turning point is reduced to 0.59.

With respect to the HDI of the importer, the relationship is U-shaped, but the results are not robust to different specifications.

Table 3 presents the results from the dynamic model – equation (4) – estimated in first differences and using instruments. Since the coefficient of the lagged dependent variable is not statistically significant, this indicates that, for our specific sample, dynamics does not play a role in the model specification. We therefore rely on the results presented in Table 2.

3.3 Robustness Analysis

Firstly, as a robustness check we estimate a specification by using an alternative technological innovation index. In particular, we use a measure of the technological capabilities of a country which was introduced by Archibugi and Coco (2004), the ArCo index,[3] which has been also used in empirical research with a gravity framework (Márquez-Ramos, 2007). The authors take three dimensions into account: creation of technology, diffusion of technology and development of human skills. It is calculated as a simple average of the three dimensions. The creation of technology index includes number of patents and number of scientific papers, which represent a form of codified knowledge generated in the country. Patents are a good proxy for commercially exploitable technological inventions and scientific literature represents the knowledge generated in the public sector.

The diffusion of technology index is measured by three indicators: Internet penetration, telephone penetration and electricity consumption. The Internet represents the newest form of technology diffusion and its penetration is measured by the data on users. Telephone penetration includes the number of telephones mainlines, which are a fundamental infrastructure for economic and social life, and the number of mobile phones, which are the

[3] One advantage of the ArCo index compared with the TAI index is that it is calculated for a larger number of countries and it allows comparisons over time.

natural evolution of telecommunications. Electric power consumption represents the diffusion of old innovations. Telephony and electricity indices are expressed in natural logarithms.

Finally, the development of human skills index includes three indicators, gross tertiary science and engineering enrolment, mean years of schooling and adult literacy rate in a country. The first indicator gives an idea of the formation of human capital in science and technology. It is obtained by multiplying gross tertiary enrolment in the population and the percentage of tertiary students in science and engineering. Mean years of schooling represents the average number of years of school completed in the population over 14 years old and it gives an indication of the level of human skills. Adult literacy is the percentage of people over 14 years old who can read and write. It is considered by the authors as a necessary condition for the development of human skills.

Secondly, in relation to the specification of the country-pair effects, we considered an attractive alternative approach, which is especially suitable when there are missing values and the time span is short, and consists of estimating the model, as proposed by Mundlak (1978), including within and between effects (Egger and Url, 2006). Basically, this approach involves modelling the correlation of unobserved heterogeneity under the assumption that the unobserved factors are correlated with the group mean of the explanatory variables. The extended model is given by:

$$\begin{aligned}\ln X_{ijt} &= \delta_i + \alpha_1 \cdot \ln Y_{it} + \alpha_2 \cdot \ln Y_{jt} + \alpha_3 \cdot \ln YH_{it} + \alpha_4 \cdot \ln YH_{jt} + \alpha_5 \cdot Adj_{ij} + \alpha_6 \cdot Land_i + \\ &+ \alpha_7 \cdot Land_j + \alpha_8 \cdot RIA_{ijt} + \alpha_9 \cdot \ln Dist_{ij} + \alpha_{10} \cdot Lang_{ij} + \alpha_{11} \cdot ArCo_{it} + \alpha_{12} \cdot ArCo_{jt} \qquad (5) \\ &+ \alpha_{13} ArCo_{it}^2 + \alpha_{14} ArCo_{jt}^2 + \alpha_{15} AV\ln Y_i + \alpha_{16} AV\ln Y_j \alpha_{17} AV\ln YH_i \alpha_{18} AV\ln YH_j + u_{ijt}\end{aligned}$$

where variables starting with AV refer to averages over time of the time-variant regressors that were described above. According to Mundlak (1978), the heterogeneity bias will be minimal, due to the fact that the correlation between the country-pair effects and the explanatory variables is captured in the model. FGLS estimation of equation (3) will provide similar estimates to the within transformation and, therefore, unbiased estimates.

Results are shown in Table 4, where we use the ArCo index as a proxy for absorptive capacity to estimate equation (3). The main shortcoming is that we only have data for 1990 and 1999 and we cannot rely on the within variation of the index to estimate our model. We, therefore, rely on a random effects estimator with added regressors to control for the remaining unobservable heterogeneity that is correlated with the fixed part of the error term. We add the averages over time of the time variant regressors, income and income per capita variables, following Mundlak (1978), Egger and Pfaffermayer (2004) and Egger and Url (2006). With

respect to the ArCo index, we used the two years available in the first estimation (column (7) of Table 4), whereas in the second and third specifications, columns (8) and (9), we used the index in 1990 and 1999, respectively. In doing so we are able to compare the results. Since column (7) shows the more conservative estimates, we have chosen those to estimate the quadratic relationship whose results are shown in column (10) of Table 4. These results confirm the existence of an inverted U-shaped relationship between exports and absorptive capacity in the exporter country with a turning point equal to 0.86 = 9.15/(2*5.327). Our results show that the relationship between ArCo and imports also shows the same shape as when using the HDI, but with a lower turning point equal to 0.71 =7.566/(2*5.327).

4. Conclusions

This paper aims to provide empirical evidence on the relationship between technological innovation achievement and bilateral exports at macro-level in a panel data framework. In order to do so, technological achievement is understood as absorptive capacity. The HDI and the ArCo indices are used in the empirical analysis, as they are considered suitable measures of technological innovation and are available for several years.

Our findings indicate a positive and non-linear effect of technological innovation on export performance. Firstly, in the case of absorptive capacity measured by the HDI, an inverted U-shaped relationship with exports is observed. Secondly, the non-linear relationship also holds when the ArCo index is used. As in Márquez-Ramos and Martínez-Zarzoso (2010), our results are consistent with the "learning-by-doing" and the "absorptive capacity" concepts. Thirdly, a U-shaped relationship is observed between human development and imports, however, the results are not robust to different specifications. Finally, when the ArCo index is used, the relationship between imports and technological achievement in the importer country also presents an inverted U-shaped relationship.

A natural extension of this research would be to investigate the question of whether the causality relationship could go from trade to technological innovation in a panel data framework.

Table 1. Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
lx	16313	10.033	3.155	1.609	19.180
lyi	19695	25.110	1.724	21.757	29.813
lyj	19695	25.110	1.724	21.757	29.813
lpi	21125	16.473	1.495	12.337	20.949
lpj	21125	16.473	1.495	12.337	20.949
adj	20800	0.033	0.179	0	1
landi	21125	0.108	0.310	0	1
landj	21125	0.108	0.310	0	1
ria	20800	0.343	0.875	0	5
ldist	20800	8.658	0.879	4.037	9.889
lang	20800	0.138	0.344	0	1
hdi_i	18070	0.765	0.158	0.258	0.961
hdi_j	18070	0.765	0.158	0.258	0.961
arcoi	21125	0.400	0.181	0.069	0.870
arcoj	21125	0.400	0.181	0.069	0.870

Table 2. Results for the static model

	(1)	(2)	(3)	(4)
	re	fe	fe1	fe3
Dep. Var.	lx	lx	lx	xnom
lyi	1.047***	1.620***	0.768**	0.864
	(56.233)	(5.527)	(2.283)	(1.605)
lyj	0.823***	1.660***	2.108***	1.561***
	(44.417)	(5.536)	(5.877)	(3.734)
lyhi	0.497***	0.098	0.971***	0.414
	(6.33)	(0.308)	(2.705)	(0.677)
lyhj	0.268***	-0.857***	-1.312***	-0.277
	(3.474)	(-2.84)	(-3.623)	(-0.648)
adj	0.647***			
	(4.105)			
landi	-0.239***			
	(-2.596)			
landj	-0.529***			
	(-5.706)			
ria	0.111***	0.134***	0.138***	0.133***
	(5.548)	(5.871)	(6.042)	(3.678)
ldist	-0.990***			
	(-26.033)			
lang	0.588***			
	(7.169)			
L.hdi_i	2.677***	3.365**	15.725***	7.048
	(5.363)	(2.481)	(4.718)	(1.589)
L.hdi_j	2.165***	-1.187	-6.954**	-5.947
	(4.5)	(-1.039)	(-2.264)	(-1.626)
L.hdi2_i			-9.942***	-6.079**
			(-4.369)	(-1.99)
L.hdi2_j			4.629**	0.151
			(2.03)	(0.065)
t3	-0.464***	-0.480***	-0.439***	-0.352***
	(-12.472)	(-6.214)	(-5.301)	(-4.364)
t4	-0.679***	-0.699***	-0.603***	-0.432***
	(-15.528)	(-5.462)	(-4.186)	(-3.506)
t5	-1.085***	-1.099***	-0.947***	-0.475***
	(-24.285)	(-6.908)	(-5.022)	(-2.96)
cons	-39.257***	-68.095***	-63.335***	
	(-50.86)	(-8.54)	(-7.493)	
r2_w	0.314	0.32	0.324	
r2_o	0.75	0.48	0.39	
N	9676	9676	9676	10437
rmse	0.89	0.74	0.74	
ll		-10807.86	-10776.64	-1.79E+08
Hausman	chi2(9) =-521.85			
Turning Point			0.791	
			0.751	

Notes: ***, **, * indicate significance at 1%, 5% and 10%, respectively. T-statistics are in brackets. The dependent variable is the natural logarithm of exports in value in columns (1)-(3), whereas the dependent variable is in levels in column (4).

Table 3. Results for the dynamic model

	(5)	(6)
	iv1	**iv2**
LD.lx	0.055	0.084
	(0.646)	(0.947)
D.lyi	0.949*	-0.699
	(1.652)	(-0.864)
D.lyj	0.717	1.274
	(1.205)	(1.594)
D.lyhi	-0.276	1.151
	(-0.513)	(1.591)
D.lyhj	0.404	-0.158
	(0.671)	(-0.2)
D.ria	0.170***	0.164***
	(5.741)	(5.368)
LD.hdi_i	1.772	24.818***
	(1.104)	(3.354)
LD.hdi_j	-8.770***	-15.417**
	(-5.691)	(-2.558)
LD.hdi2_i		-11.692***
		(-2.599)
LD.hdi2_j		4.084
		(1.019)
cons	-0.091	-0.119
	(-1.394)	(-0.804)
N	2303	2142
rmse	0.79	0.80
ll	-2723.35	-2557.80
j	0.11	0.05
jp	0.74	0.83
estat		1.06
estatp		0.30

Notes: ***, **, * indicate significance at 1%, 5% and 10%, respectively. T-statistics are in brackets.

Table 4. Results with ArCo index

	(7)	(8)	(9)	(10)
	re	re1	re2	re3
lyi	-0.247*	-0.434***	-0.446***	-0.412***
	(-1.764)	(-3.205)	(-3.293)	(-2.889)
lyj	0.016	-0.051	-0.059	-0.121
	(0.115)	(-0.382)	(-0.445)	(-0.861)
lyhi	1.234***	1.503***	1.506***	1.303***
	(8.018)	(10.264)	(10.291)	(8.462)
lyhj	0.478***	0.573***	0.576***	0.548***
	(3.166)	(4.006)	(4.026)	(3.624)
adj	0.766***	0.778***	0.765***	0.717***
	(5.086)	(5.155)	(5.14)	(4.761)
landi	-0.323***	-0.373***	-0.319***	-0.272***
	(-3.697)	(-4.242)	(-3.704)	(-3.109)
landj	-0.590***	-0.637***	-0.595***	-0.544***
	(-6.731)	(-7.218)	(-6.879)	(-6.201)
fta	0.064***	0.075***	0.065***	0.079***
	(3.377)	(4.009)	(3.456)	(4.202)
ldist	-0.938***	-0.923***	-0.947***	-0.949***
	(-27.335)	(-26.841)	(-27.907)	(-27.68)
lang	0.762***	0.778***	0.833***	0.751***
	(10.62)	(10.817)	(11.717)	(10.467)
arcoi	1.644***			9.150***
	(6.171)			(10.053)
arcoj	0.643**			7.566***
	(2.385)			(8.344)
arcoi2				-5.745***
				(-8.658)
arcoj2				-5.327***
				(-8.034)
arcoi1990		2.959***		
		(7.939)		
arcoj1990		2.210***		
		(5.904)		
arcoi1999			3.811***	
			(12.686)	
arcoj1999			2.187***	
			(7.248)	
avlyi	1.250***	1.429***	1.444***	1.420***
	(8.88)	(10.492)	(10.621)	(9.89)
avlyj	0.776***	0.834***	0.849***	0.917***
	(5.585)	(6.214)	(6.333)	(6.461)
avlyhi	-0.634***	-1.067***	-1.306***	-1.141***
	(-4.216)	(-6.725)	(-8.259)	(-6.985)
avlyhj	0.041	-0.268*	-0.333**	-0.431***
	(0.279)	(-1.725)	(-2.15)	(-2.681)
R^2	0.72	0.72	0.72	0.72
N	14455	14455	14455	14455
rmse	1.01	1.00	1.00	1.00
Time dummies	Yes	Yes	Yes	Yes

Notes: ***, **, * indicate significance at 1%, 5% and 10%, respectively. T-statistics are in brackets.

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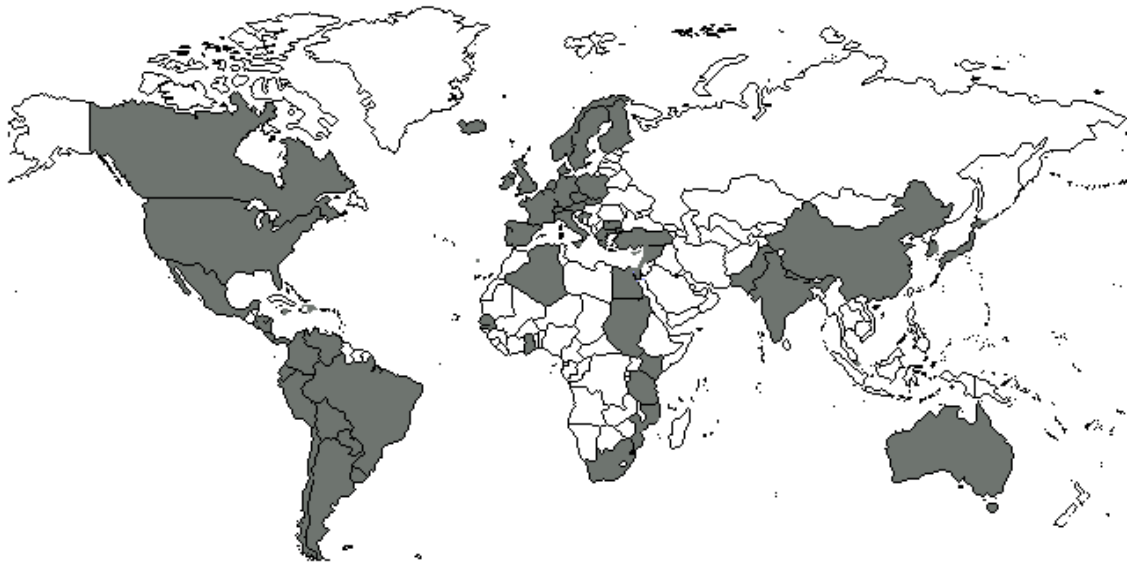
APPENDIX

Figure A.1. Selected countries.



Algeria
Argentina
Australia
Austria
Belgium-Luxembourg
Bolivia
Brazil
Bulgaria
Canada
Chile
China
Colombia
Costa Rica
Croatia
Cyprus
Czech Republic
Denmark
Dominican Republic
Ecuador
Egypt, Arab Rep.
El Salvador
Finland
France
Germany
Ghana
Greece
Honduras
Hong Kong, China
Iceland
India
Ireland
Israel
Italy
Jamaica
Japan
Kenya
Korea, Rep.
Mexico
Mozambique
Nepal
Netherlands
Nicaragua
Norway
Pakistan
Panama
Paraguay
Peru
Poland
Portugal
Senegal
Singapore
Slovak Republic
South Africa
Spain
Sudan
Sweden
Switzerland
Syrian Arab Republic
Tanzania
Trinidad and Tobago
Turkey
United Kingdom
United States
Uruguay
Venezuela

Developed countries: Argentina, Australia, Austria, Belgium-Luxembourg, Canada, Chile, Costa Rica, Cyprus, Czech Republic, Denmark, Finland, France, Germany, Greece, Hong Kong, Iceland, Ireland, Israel, Italy Japan, Netherlands, Norway, Poland, Portugal, Rep. Korea, Singapore, Slovak Republic, South Africa, Spain, Sweden, Switzerland, United Kingdom, United States, Uruguay.

Developing countries: Algeria, Arab Rep. Egypt, Bolivia, Brazil, Bulgaria, China, Colombia, Croatia, Dominican Republic, Ecuador, El Salvador, Ghana, Honduras, India, Jamaica, Kenya, Mexico, Mozambique, Nepal, Nicaragua, Panama, Pakistan, Paraguay, Peru, Senegal, Syrian Arab Republic, Tanzania, Trinidad and Tobago, Turkey, Venezuela.

Table A.1: Variable descriptions and sources of data.

Variable	Description	Source
X_{ij} : Exports from i to j	Nominal value of bilateral exports	Statistics Canada (2001)
Y_i : Exporter's income	Exporter's GDP, PPP (current international $)	World Bank (2001)
Y_j : Importer's income	Importer's GDP, PPP (current international $)	World Bank (2001)
YH_i : Exporter's income per capita	Exporter's income/Total population in the exporter's market	World Bank (2001)
YH_j : Importer's income per capita	Importer's income/Total population in the importer's market	World Bank (2001)
Adj_{ij} : Adjacency dummy	Dummy variable = 1 if the trading partners share a border, 0 otherwise	CIA (2003)
Land: Landlocked dummy	Dummy variable = 1 if the country is landlocked, 0 otherwise	CIA (2003)
FTA	RIAs variable	Márquez-Ramos et al (2009)
$Dist_{ij}$: Distance	Great circle distances between country capitals of trading partners (km)	Great circle distances between cities (2003)
$Lang_{ij}$ *:* Language dummy	Dummy variable = 1 if the trading partners share the same official language, 0 otherwise.	CIA (2003)
HDI_i: Exporter's HDI	Technological innovation in the exporting country	UNDP (2001), several years
HDI_j: Importer's HDI	Technological innovation in the importing country	UNDP (2001), several years
$ArCo_i$	Technological innovation in the exporting country	Archibugi and Coco (2004)
$ArCo_j$	Technological innovation in the importing country	Archibugi and Coco (2004)

Note: UNDP denotes United Nations Development Programme and CIA denotes Central Intelligence Agency.

Table A.2. Human Development Index and its components in 1995.

Importer	life_expectancy_index_j	education_index	GDP_index	HDI_1995
Bulgaria	0.764	..	0.716	..
Ghana	0.568	..	0.381	..
Hong Kong, China	0.902	..	0.952	..
Jamaica	0.772	..	0.693	..
Kenya	0.541	..	0.440	..
South Africa	0.591	..	0.726	..
Sudan	0.491	..	0.417	..
Norway	0.880	0.965	1.000	0.948
United States	0.861	0.975	0.982	0.939
Canada	0.888	0.989	0.937	0.938
Netherlands	0.876	0.988	0.950	0.938
Australia	0.889	0.993	0.931	0.938
Sweden	0.895	0.985	0.932	0.937
Belgium-Lux	0.866	0.993	0.941	0.933
Japan	0.916	0.929	0.948	0.931
Switzerland	0.893	0.922	0.976	0.931
United Kingdom	0.864	0.993	0.930	0.929
France	0.880	0.964	0.938	0.927
Austria	0.864	0.947	0.949	0.920
Germany	0.861	0.950	0.946	0.919
Iceland	0.898	0.939	0.918	0.918
Denmark	0.844	0.960	0.947	0.917
Finland	0.857	0.984	0.906	0.916
Spain	0.884	0.949	0.909	0.914
Italy	0.884	0.901	0.933	0.906
Ireland	0.846	0.951	0.911	0.903
Singapore	0.861	0.823	0.969	0.884
Israel	0.877	0.874	0.899	0.883
Greece	0.871	0.876	0.875	0.874
Portugal	0.837	0.903	0.870	0.870
Cyprus	0.874	0.850	0.875	0.866
Czech Republic	0.812	0.906	0.851	0.857
Korea, Rep.	0.809	0.861	0.843	0.837
Slovak Republic	0.790	0.906	0.784	0.827
Argentina	0.795	0.907	0.771	0.824
Poland	0.785	0.928	0.755	0.823
Chile	0.833	0.871	0.763	0.822
Uruguay	0.809	0.897	0.745	0.817
Croatia	0.810	0.869	0.755	0.811
Costa Rica	0.863	0.835	0.724	0.807
Trinidad and Tobago	0.734	0.872	0.786	0.797
Mexico	0.796	0.809	0.777	0.794
Venezuela, RB	0.781	0.819	0.781	0.793
Panama	0.802	0.828	0.723	0.784
Ecuador	0.771	0.820	0.683	0.758
Colombia	0.740	0.820	0.711	0.757
Peru	0.717	0.842	0.673	0.744
Brazil	0.722	0.745	0.735	0.734
Turkey	0.710	0.726	0.753	0.730
Paraguay	0.732	0.810	0.636	0.726
El Salvador	0.730	0.691	0.652	0.691
Dominican Republic	0.743	0.702	0.613	0.686

China	0.743	0.731	0.496	0.657
Algeria	0.724	0.552	0.682	0.653
Bolivia	0.602	0.762	0.595	0.653
Syrian Arab Republic	0.757	0.576	0.615	0.649
Egypt, Arab Rep.	0.680	0.605	0.607	0.631
Honduras	0.725	0.581	0.564	0.623
Nicaragua	0.706	0.592	0.493	0.597
India	0.577	0.504	0.451	0.511
Pakistan	0.619	0.291	0.497	0.469
Nepal	0.541	0.410	0.358	0.436
Tanzania	0.415	0.504	0.357	0.425
Senegal	0.470	0.288	0.439	0.399
Mozambique	0.348	0.341	0.242	0.310

Source: UNDP (2010), http://hdr.undp.org/en/