The effect of technological innovation on international trade. A non-linear approach

LAURA MÁRQUEZ-RAMOS*
Universitat Jaume I and Instituto de Economía Internacional, Castellón (Spain)
E-mail: lmarquez@eco.uji.es

INMACULADA MARTÍNEZ-ZARZOSO*
Universitat Jaume I and Instituto de Economía Internacional, Castellón (Spain)
Ibero-America Institute for Economic Research, Göttingen (Germany)
E-mail: martinei@eco.uji.es

Abstract

In this paper, the effect of technological variables on sectoral exports is analysed using a gravity model of trade. The technological achievement index (TAI) and its four dimensions are used as proxies for technological innovation. We hypothesise that the effect of technological innovation on trade could vary according to technological achievement by generating a non-linear relationship between technological innovation and trade. Our findings indicate a positive and linear effect of technological innovation on export performance when using the overall index. However, the relationship becomes non-linear for specific components of the index, which indicates that there are thresholds for positive signs to occur. Whereas creation of technology is associated with higher and increasing exports, a "U-shaped" relationship is observed between diffusion of old innovations and exports, while an inverted-"U-shaped" relationship is found between diffusion of recent innovations, and human skills and exports. Hence, to foster exports, countries have to consider not only the capacity to create technological innovation, but also the "absorptive capacity" once a minimum level of basic technological innovation has already been achieved.

* We would like to thank two anonymous referees and the editor for their very helpful comments and suggestions. Financial support from both the Spanish Ministry of Public Works and the Spanish Ministry of Science and Technology is gratefully acknowledged (P21/08 and SEJ 2007-67548).

1. Introduction

The international trade theory highlights the importance of technological innovation in explaining a country's international competitiveness (Posner, 1961, Vernon, 1966, Fagerberg, 1997). According to Schumpeter (1883-1950), economic development is a dynamic process deriving from industry and trade. This author identifies different causes of economic development related to trade such as introducing a new quality of a good, or a new use of an already existing good, a new production method, opening up of a new market, and a change in economic organisation. Then, technological innovation can be defined as the countries' capacity to put new ideas into practice by developing new products and processes which play a key role in international trade and economic development. Therefore, the development of relevant indicators to measure the level of technological innovation across countries is of great interest in a knowledge-based economy with a high and increasing dependence on information technology and human capital. Kuznets (1962) already noted the problems that the lack of appropriate innovation measures may create in economic research related to inventive activity. In recent years, considerable attempts have been made to measure technology creation and diffusion, and human skills across countries. Márquez Ramos, Martínez Zarzoso, Sanjuán Lucas and Suárez Burguet (2007) have recently compiled a number of indices and variables to measure the achievement of technological innovation. Nonetheless, a nation's technological achievements are very complex. Therefore, it is difficult to capture them in an index that reflects the full range of technologies and which quantifies some aspects of technology creation, diffusion and human skills. In order to overcome these inconveniences, the Technological Achievement Index (TAI) has been used in empirical analyses (Martínez Zarzoso and Márquez Ramos, 2005). This index has been constructed using indicators of a country's achievements in four dimensions: creation of

technology, diffusion of recent innovations, diffusion of old innovations and human skills.

From a gravity framework, empirical applications show that heterogeneity matters in technological innovation. Loungani, Mody and Razin (2002) distinguish between developed and developing countries when analysing whether better "informational infrastructure" can substitute geographical distance. Their results indicate the existence of country-heterogeneity in the different determinants of international trade. Fink, Mattoo and Neagu (2005) analyse the effect of communication costs on bilateral trade flows by taking into account sector-heterogeneity. Their results show that communication costs have a significant effect on international trade and that they are of greater importance for trading differentiated products than for trading homogeneous products. Then, technological innovation is seen to have a greater effect on the trade of differentiated goods since information asymmetries exist; therefore, there is a lower demand of this type of goods in foreign markets.

The main aim of this paper is to investigate whether the effect of technological innovation on trade is non-linear, which would indicate that the effect of improved technological innovation on trade could vary according to the technological achievement in countries. This effect is also analysed separately for developed and developing countries, as well as for different sectors.

The results show that a non-linear relationship exists between exports and diffusion of old innovations, which is "U-shaped", whereas an inverted-"U-shaped" relationship is found between exports and diffusion of recent innovations and between exports and human skills.

The paper is arranged as follows: Section 2 presents the theoretical framework and the main hypothesis. Section 3 describes the sample selection. Section 4 describes data

sources and variables. Section 5 presents the estimation strategy, the main results and a number of robustness checks. This section also presents an endogeneity analysis. Technological variables can be considered endogenous in the gravity model of trade since higher trade among countries deals with higher technological innovation. A final section summarises the main findings.

2. Theoretical framework and the main hypothesis

The last few decades have witnessed important changes in international trade patterns, with an increasing number of countries that are closely linked to one another through international trade and foreign direct investment. Technological innovation plays an important role in this world-wide interdependence. Within this framework, international trade theory highlights the importance of technological innovation in explaining the international competitiveness of a country (Fagerberg, 1997).

Classical thinking, which stressed international differences in technology in conjunction with international differences in real wage levels as a source of comparative advantage, dominated trade theory until the appearance of the Heckscher-Ohlin (H-O) theory which centred on resource endowments as the main factor explaining international trade patterns.[1] Nevertheless, technological innovation once again came to the forefront of research into trade with the development of the technology gap (Posner, 1961) and the product-cycle theories (Vernon, 1966). On the one hand and according to Posner's assumptions (1961), trade is generated by differences in the rate and nature of innovation. On the other hand, Vernon (1966) places less emphasis on the comparative cost doctrine and more on the timing of innovation.

Jones (1970) considered the way in which the H-O model could be applied to Vernon's product-cycle theory. Vernon argued that developed countries tend to have a

[1] Jones (1970) states that "in a sense, the Heckscher-Ohlin model represents a step backward from the earlier Ricardian tradition" (page 78).

comparative advantage in producing those commodities that are newly developed, suggesting a three-factor model: capital, "ordinary" labour, and human skills. Developed countries have a relative abundance of the third factor and, hence, a comparative advantage in producing new commodities at early stages of production. Additionally, Jones (1970) also highlighted the view that technology is improved because there is "learning by doing". According to this concept, the higher the level of production (or the more "experience" about techniques gained by using them), the greater the rate at which these techniques become more productive. Since those newly developed techniques in an advanced country must be devoted to the learning process before they can be utilised in a developing country, technology is not kept “secret”, but technology transmission has a cost. Additionally, Cohen and Levinthal (1990) introduced the concept of “absorptive capacity”, which is the ability to recognise the value of new, external information, assimilate it, and apply it. Along these lines, therefore, when analysing the relationship between technological innovation and trade, not only the learning process matters, but also the capacity to adapt technological innovation in a particular environment.

More recently, Eaton and Kortum (2002) developed a Ricardian model to explore the role of trade in spreading the benefits of technological innovation. Their theory delivers an augmented gravity equation for bilateral trade that identifies the underlying parameters of technological innovation. Their results indicate that foreigners benefit by only a tenth as much as the innovating country, but the benefits depend on the distance to trading partners; in fact close neighbours benefits are close to those of the innovator.

We go one step further and wonder whether the benefits, in terms of trade, derived from technological innovation depend not only on the origin of the innovation (home or foreign), but also on the level of technological innovation in each country. Hence, we

investigate the existence of a non-linear relationship which causality goes from technological innovation to trade, and accounts for the fact that different stages of the learning process may play a role in determining this relationship.

Our first hypothesis is that the relationship between technological innovation and trade may present a different functional form depending on the technological innovation dimension which is analysed. Our results support this first hypothesis since a "U-shaped" relationship is found between exports and diffusion of old innovations, whereas an inverted-"U-shaped" relationship is found between exports and "absorptive capacity" measures.

Additionally, the learning process may affect differently developed and developing countries. Thus, our second hypothesis indicates that less developed countries may need a minimum technological level to obtain trade gains derived from higher technological achievements, whereas the "already achieved" technological level in developed countries is sufficient to obtain trade gains from further technological developments. This hypothesis is consistent with the results obtained in this paper, which shows a "U-shaped" relationship between technological innovation and trade when the importer is a developing country.

With respect to the type of products traded, it has been widely recognised that innovation and technological developments are more relevant for sophisticated products (differentiated and high-technology) than for homogeneous goods. Thus, we hypothesise that the relationship between technological innovation and trade should be more robust for differentiated products for which creation of technology is going to foster exports. The results obtained in the present paper show that technological improvements have a greater effect on exports of differentiated and high-technology goods for intermediate levels of technological achievements. This result is consistent

with the fact that the more experience in techniques gained by producing goods that embody a high technological content, the greater the exports.

3. Sample selection

In a first step, a revealed comparative advantage (RCA) index is used to select a representative country sample that represents different specialisation patterns. The RCA index is calculated according to Balassa's measure of relative export performance by country and industry (1965) to determine in which goods are specialised the countries being considered in the analysis. The index is defined as a country's share of world exports of a given good divided by its share of total world exports, as expressed in Equation (1):

$$\boldsymbol{RCA_{ik}} = \frac{\boldsymbol{X_{ik}} / \boldsymbol{X_{wk}}}{\boldsymbol{X_{iN}} / \boldsymbol{X_{wN}}} \cdot 100 \qquad (1)$$

where RCA_{ik} is the RCA index of commodity k for country i, X_{ik} is the value of commodity k exported by country i, X_{wk} is the value of world exports of commodity k, X_{iN} is the value of the exports of all the commodities by country i, and X_{wN} is the value of world exports of all the commodities. A ranking of the first ten industries with the highest positive RCA values is drawn up for a 65-country sample in the year 2000.[2] According to Equation (1), country i has a comparative advantage in exporting commodity k when RCA_{ik} is greater than one.

In a second step, a classification matrix is constructed to choose a representative sample for the sectoral analysis (in boldface in Table 1). Classifications by country (developed and developing countries) and by commodity (Rauch, 1999: differentiated, reference-priced and homogeneous) are considered. The information in Márquez Ramos (2007) is used to determine whether countries specialise in differentiated, reference-priced or homogeneous goods. Thirteen representative exporters are chosen for the empirical

[2] See Márquez Ramos (2007), pp. 142-156.

analysis as follows: Bolivia, Brazil and Chile for Latin America; the United States for North America; China and Japan for Asia; the Czech Republic, Germany, Spain and the United Kingdom for Europe; Ghana and South Africa for Africa; Australia for Oceania.

Table 1. Classification matrix.

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

Note: Countries are classified into three groups as follows: countries are ordered from higher to lower income levels (GDP per capita, PPP in 1999. Source: WDI, 2005), then an upper level and inferior level of GDP are calculating by the average of the first half and the average of the second half of the sample, respectively. Commodities are classified according to Rauch (1999).

4. Data, sources and variables

Bilateral trade data by commodity derive from Feenstra, Lipsey, Deng, Ma and Mo (2005). The level of disaggregation chosen is 4-digit SITC. The final sample includes 13 exporters and 77 importers in the year 2000.

The databases used to construct the exogenous variables for the regression analysis are World Development Indicators (2005) for incomes, World Integrated Trade Solution (WITS) for tariffs, and Doing Business (2006) database for transport costs. This database was recently created by the World Bank and it compiles procedural requirements for exporting and importing a standardised cargo of goods. Distance between capitals, common official language and the colonial dummy were taken from CEPII.[3]

Two types of variables are used: income, technological innovation, transport costs, geographical, cultural and integration dummies vary across countries, whereas tariffs, high-technology and sectoral dummies vary across sectors. Technological innovation is proxied using the TAI, which is a measure introduced by the UNDP in its Human Development Report of 2001. The TAI aims to capture how well a country as a whole is participating in creating, using and diffusing technology and in building a human skill base to acquire knowledge. A nation's technological achievements are very complex and, therefore, it is difficult to capture them in an index that reflects the full range of technologies and which quantifies some aspects of technology creation, diffusion and human skills. In order to overcome these inconveniences, the TAI was constructed using indicators of a country's achievements in four dimensions: creation of technology, diffusion of recent innovations, diffusion of old innovations and human skills. The creation of a technology index represents the capacity to innovate. Two indicators are used to capture the level of innovation in a country. The first is the *number of patents granted to residents*, which reflects the current level of invention activities. The second indicator is *receipts of royalty and license fees from abroad*, which indicates the stock

[3] The dist_cepii file was taken from http://www.cepii.fr/anglaisgraph/bdd/distances.htm. The language variable is based on the fact that two countries share a common official language (comlang_off). Simple distances are calculated following the great circle formula which uses latitudes and longitudes of the most important cities/agglomerations (in terms of population).

of successful innovations made in the past that are still useful. Two additional indicators measure the diffusion of old innovations, namely *number of telephones* and *electricity consumption*. These indicators are important since both are needed to use new technologies and basic related activities. Electricity consumption is also considered a proxy for the use of machinery and equipment since most of it is run by electric power. Two indicators are used to measure the diffusion of recent innovations. The first, *Internet hosts*, reflects the diffusion of the Internet which enables the fastest transfer of information and an easier adaptation of firms and organisations in a changing environment. The second, *exports of high technology and medium technology products*, which illustrates the country's level of specialisation in technologically intensive goods. Finally, the human skills index is measured by two indicators: *mean years of schooling*, representing the fact that people can be users of technology if they have a basic education on which to develop cognitive skills; and the *gross tertiary science enrolment ratio*, showing that the higher the number of inhabitants with the ability to develop skills in science, mathematics and engineering, the greater the number of technology creators. Both diffusion of recent innovation and the human skills indexes are used as proxies of "absorptive capacity" in the present paper.

Scores are derived as an index in relation to the maximum and minimum achieved by countries in any indicator of these dimensions. The performance of each index takes a value of between 0 and 1 which is calculated according to Equation (2).

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

The TAI is calculated as a simple average of the four dimension indices, based on the assumption that components play a comparable role of a country's technological achievement. The TAI provides a summary of a society's technological achievements and it allows countries to be classified into four groups according to their level of

technological innovation: Leaders (TAI>0.5), Potential Leaders (0.35<TAI<0.49), Dynamic Adopters (0.19<TAI<0.34) and Marginalised (TAI<0.19). Table A.1 shows the list of countries classified in all four groups where, for instance, Spain is classified as a potential leader, whereas Finland has the highest score in the group of technological leaders. The lowest score goes to Mozambique which is classified within the group of technologically marginalised countries.

The high-technology dummy is based on the classification of the Spanish National Statistics Institute (INE).[4] Commodities are defined using the Standard International Trade Classification (SITC), revision 3 at the 4-digit level. Concordances from the Centre for International data at UC Davis between SITC revisions 2 and 3 are used since trade data are defined according to SITC revision 2. Finally, the sectoral dummies are based on Rauch (1999) and were obtained from Jon Haveman's International Trade data web page. Table A.2[5] shows a summary of the data and sources used in this paper.

5. Empirical analysis

5.1. Determinants of sectoral trade

In order to analyse the effect of technological innovation on sectoral trade, a gravity equation is specified (Bergstrand, 1985, 1989; Deardorff, 1995) and estimated for the disaggregated data. The estimated equation is:

$$\begin{aligned}
\ln X_{ijk} &= \alpha_0 + \alpha_1 \cdot \ln Y_i + \alpha_2 \cdot \ln Y_j + \alpha_3 \cdot Adj_{ij} + \alpha_4 \cdot Land_i + \alpha_5 \cdot Land_j + \\
&+ \alpha_6 \cdot MERC + \alpha_7 \cdot NAFTA + \alpha_8 \cdot CAN + \alpha_9 \cdot EU + \alpha_{10} \cdot EMU + \\
&+ \alpha_{11} \cdot ECOWAS + \alpha_{12} \cdot CEFTA + \alpha_{13} \cdot \ln Dist_{ij} + \alpha_{14} \cdot Lang_{ij} + \\
&+ \alpha_{15} \cdot Colony_{ij} + \alpha_{16} \cdot TAI_i + \alpha_{17} \cdot TAI_j + \alpha_{18} \cdot (TAI_i)^2 + \alpha_{19} \cdot (TAI_j)^2 + \\
&+ \alpha_{20} \cdot \ln Tariffs_{ik} + \alpha_{21} \cdot \ln TC_i + \alpha_{22} \cdot \ln TC_j + \alpha_{23} \cdot high_tech_k + \alpha_{24} \cdot \mathrm{hom}_k + \\
&+ \alpha_{25} \cdot ref_k + \alpha_{26} \cdot DP + \varepsilon_{ijk}
\end{aligned} \tag{3}$$

[4] "List of High-Technology products according to SITC codes and corresponding to codes CNPA-96 and PRODCOM", INE, 2006.

[5] Table A.2 in the Appendix. The first column lists the variables used for the empirical analysis; the second column outlines a description of the variables, and the third column shows the data sources.

where *ln* denotes natural logarithms. X_{ijk} denotes the value of exports of commodity k from country i to j; Y_i and Y_j are the incomes in the exporter's market and in the destination market, respectively; Adj_{ij} is a dummy that indicates whether the trading partners are contiguous; $Land_i$ and $Land_j$ take the value of 1 when the exporting or importing countries are landlocked, respectively, and zero otherwise.

MERC is a dummy that takes a value of 1 when both exporting and importing countries belong to Mercosur; NAFTA takes a value of 1 when countries are members of the North American Free Trade Area, and CAN is a dummy representing Andean Community members. EU takes a value of 1 when countries are members of the European Union. Additionally, EMU takes a value of 1 when countries are members of the Economic and Monetary Union;[6] ECOWAS takes a value of 1 when countries are members of the Economic Community of West African States. Finally, CEFTA takes a value of 1 when countries are members of the Central European Free Trade Agreement.

$Dist_{ij}$ is the geographical great circle distance in kilometres between the most important cities (in terms of population) of country i and j. $Lang_{ij}$ is a dummy for countries sharing a common official language. $Colony_{ij}$ is a dummy that takes the value of 1 when trading partners have had a colonial link at any time.

As previously indicated, the TAI is used to measure the technological innovation in countries i and j. Then, TAI_i and TAI_j are the technological variables measuring technological innovation in the exporting and importing countries. To analyse the individual effect of the different dimensions composing the TAI on international trade, four additional regressions were derived from Equation (3) where TAI can be substituted by its four dimensions. In order to analyse the existence of a non-linear relationship between technological innovation and international trade, two additional

[6] Greece is also considered because, on 15 January 2000, the Greek government announced the drachma-euro exchange rate with which Greece would enter the third stage of the EU Economic and Monetary Union (EMU) on 1 January 2001.

terms are included in the model, $(TAI_i)^2$ and $(TAI_j)^2$. Then, this index is decomposed into its four dimensions and the model is again estimated with the two additional terms in each dimension.

$Tariff_{ik}$ is the simple average effectively applied tariff for all the countries importing each commodity from the 13 exporters. TC_i and TC_j are the transport costs of the exporting and importing countries, respectively.

$High\text{-}tech_k$ is a dummy that takes the value of 1 when the commodity is a high-technology commodity. Hom_k takes the value of 1 when a commodity is homogeneous, and zero otherwise, whereas ref_k takes the value of 1 when a commodity is reference-priced according to the conservative Rauch classification (1999). The *DP* dummy is included in the regression to take country-heterogeneity into account. It takes the value of 1 when trading partners are richer than the sample average. Finally, ε_{ijk} is the error term, which is assumed to be independently and identically distributed.

Equation (3) is estimated using Ordinary Least Squares (OLS), Pseudo Poisson Maximum Likelihood (PPML) methods and Harvey methodologies. The Harvey model and the PPML estimator are used as alternative options to control heteroscedasticity. The PPML method is employed following the observations by Santos-Silva and Tenreyro (2006), these being that the standard empirical methods are not appropriate to estimate gravity equations. Log-linearisation leads to inconsistent estimates when observations with heteroscedasticity are present. In addition, the zero values in the dependent variable cannot be considered in the OLS estimation. Moreover, Santos-Silva and Tenreyro (2006) state that the OLS estimation of the gravity model exaggerates the role of geographical proximity and links. Their results suggest that heteroscedasticity is responsible for the main differences. To address these estimation problems, these authors propose using the PPML method.

The Harvey model controls multiplicative heteroscedasticity (Harvey, 1976), whereas the PPML method is robust to some kinds of model misspecification, such as heteroscedastic errors. Harvey (1976) proposes a general formulation of a regression model with multiplicative heteroscedasticity which is more attractive than the usual "additive" model in which the variance of the disturbances is assumed to be related to a linear combination of the known variables.

Causality in this paper is assumed to derive from technological innovation to exports; however, higher exports could also foster technological innovation. Poldahl and Gustavsson-Tingvall (2005) analyse whether an inverted-"U" relationship exists between competition and technological innovation. These authors use the Herfindahl Index as a measure of the degree of competition in the market. Their results show that breaking up monopolies leads to an increase of R&D expenditure in Swedish companies, whereas further increases in competition leads to lower R&D investment. Although the existence of endogeneity in technological innovation has been analysed using aggregated trade data (Martínez Zarzoso and Márquez Ramos, 2005), further research is required to analyse the existence of the endogeneity and inverse causality between technological innovation and sectoral trade. Thus, Equation (3) is also estimated using instrumental variables (IV).

5.2. Technological innovation and international trade

Table 2 shows the main results obtained for the technological variables considered.[7] The first part of Table 2 presents the obtained results for the overall index, while the rest of the table shows the results of its different dimensions. Columns (1), (2), (3) and (4) show the results obtained when using different estimation methods, namely the OLS, PPML, Harvey and the IV. When using the OLS, PPML and Harvey methods, the

[7] Results concerning the other explanatory variables are available upon request from the authors.

results obtained for the importer's TAI show that the index falls into the increasing part of a "U-shaped" relationship between technological innovation and exports. This indicates a possible linear relationship between trade and technological innovation. However, when applying the IV estimator the effect of technological innovation on exports is magnified for higher achievements of technological innovation in the importing country.

In terms of the exporter's TAI, for TAI values higher than 0.33 in the OLS regressions, 0.42 in the PPML regressions, and 0.35 in the Harvey regressions; exports always increase with technological innovation. Therefore, for those countries classified as potential leaders, the effect of technological innovation on exports is always positive and increases with technological improvements.

Estrada, Heijs and Buesa (2006) have shown the existence of a non-linear relationship between technological innovation and international trade. According to these authors, a non-linear relationship exists between these variables since companies require a minimum level of technological innovation to compete in world markets. At this level, the export probability would increase to innovation effort until a particular level where the export probability would be constant. Their results show that a non-linear relationship exists, particularly an inverted-"U" effect for a number of cases, and that a "U" effect between technological innovation and export probability is also possible. For instance, these authors note that those companies with a low and high R&D intensity have a higher export probability than those with a medium R&D intensity; however, other variables related to technological innovation (structural characteristics, technological acquisition and innovative results) show that an inverted-"U-shaped" relationship is also possible between the innovation level and the export probability.

Table 2. The effect of technological innovation on international trade.

	OLS (1)	**PPML[8] (2)**	**Harvey (3)**	**IV (4)**	***IV_65 countries* (5)**	***IV_13 countries aggregated* (6)**
Exporter's TAI	-1.69***	-8.29***	-2.03***	0.83***	*13.38****	*10.95****
	(-4.84)	(-4.23)	(-6.12)	(15.23)	*(9.03)*	*(3.10)*
Exporter's TAI (square)	2.56***	9.75***	2.90***	-	*-7.43****	*-9.38****
	(7.27)	(4.81)	(8.67)		*(-4.86)*	*(-2.71)*
Importer's TAI	0.07	1.74***	-0.09	0.54***	*10.26****	*1.51***
	(1.21)	(9.44)	(-1.64)	(6.92)	*(7.52)*	*(2.37)*
Importer's TAI (square)	1.05***	-	1.27***	0.31***	*-7.33****	-
	(11.43)		(14.82)	(2.91)	*(-5.10)*	
Exporter's creation of technology	-0.22**	-2.63***	0.05	-0.21*	*9.24****	*2.69***
	(-2.15)	(-5.75)	(0.54)	(-1.94)	*(13.88)*	*(2.26)*
Exporter's creation of technology (square)	1.40***	6.27***	0.92***	1.41***	*-11.43****	*-3.32**
	(8.61)	(7.77)	(5.91)	(8.46)	*(-8.55)*	*(-1.80)*
Importer's creation of technology	-0.81***	-0.77	-0.77***	-0.86***	*5.72****	*3.31****
	(-6.91)	(-1.61)	(-6.85)	(-7.29)	*(7.76)*	*(3.06)*
Importer's creation of technology (square)	2.51***	2.63***	2.45***	2.54***	*-8.06****	*-4.04***
	(10.54)	(3.33)	(10.68)	(10.63)	*(-5.36)*	*(-2.00)*
Exporter's diffusion of old innovations	-6.06***	-19.17***	-4.53***	-6.82***	*-7.73****	*1.81****
	(-9.18)	(-10.65)	(-7.41)	(-5.02)	*(-3.39)*	*(3.38)*
Exporter's diffusion of old innovations (square)	4.13***	11.66***	3.19***	4.52***	*9.18****	-
	(10.35)	(10.49)	(8.63)	(5.55)	*(6.28)*	
Importer's diffusion of old innovations	-1.36***	-0.36	-1.18***	-0.89***	*-2.36*	*-1.26**
	(-23.40)	(-0.66)	(-21.61)	(-9.04)	*(-1.36)*	*(-1.84)*
Importer's diffusion of old innovations (square)	1.47***	0.94**	1.33***	0.97***	*3.94****	*2.43****
	(25.26)	(2.15)	(24.54)	(11.52)	*(3.45)*	*(3.61)*
Exporter's diffusion of recent innovations	0.65***	3.25***	0.51***	0.95***	*7.29****	*1***
	(4.95)	(3.60)	(10.62)	(6.42)	*(11.46)*	*(1.99)*
Exporter's diffusion of recent innovations (square)	-0.26**	-3.68***	-	-0.69***	*-4.09***	-
	(-2.05)	(-3.67)		(-4.83)	*(-5.27)*	
Importer's diffusion of recent innovations	1.00***	2.25***	0.85***	1.03***	*3.81****	*1.38****
	(12.93)	(4.86)	(11.83)	(11.18)	*(6.06)*	*(4.02)*
Importer's diffusion of recent innovations (square)	-0.37***	-1.04*	-0.21**	-0.57***	*-2.09****	-
	(-3.54)	(-1.68)	(-2.16)	(-4.86)	*(-2.61)*	
Exporter's human skills	0.89***	4.37***	0.11***	1.91***	*11.19****	*6.49****
	(5.36)	(3.36)	(3.81)	(10.06)	*(10.94)*	*(3.50)*
Exporter's human skills (square)	-0.73***	-4.82***	-	-1.65***	*-6.21****	*-5.17****
	(-4.96)	(-3.75)		(-9.75)	*(-6.98)*	*(-3.21)*
Importer's human skills	-0.06	2.46***	-0.16**	0.17	*6.89****	*3.54****
	(-0.91)	(4.98)	(-2.45)	(1.35)	*(7.05)*	*(3.25)*
Importer's human skills (square)	0.47***	-1.71***	0.57***	0.19*	*-4.22****	*-1.96**
	(6.21)	(-3.58)	(7.95)	(1.67)	*(-4.76)*	*(-1.93)*
1-U Theil	0.82	0.56	0.82	0.82	*0.85*	*0.91*
R-squared	0.25	0.35	0.24[9]	0.24	*0.76*	*0.86*
Number of observations	149,985	149,992	149,985	123,250	*1,895*	*799*

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 (current US$). The OLS and IV estimation

[8]When the Poisson model is $\boldsymbol{E}[\boldsymbol{Y}_i|\boldsymbol{x}_i] = \exp[\beta_1 \boldsymbol{x}_{i1} + \beta_2 \boldsymbol{x}_{i2} + \beta_3]$, it is possible to interpret β_1 as a semi-elasticity: $\partial \log \boldsymbol{E}[\boldsymbol{Y}_i|\boldsymbol{x}_i] / \partial \boldsymbol{x}_{i1} = \beta_1$

[9] This is the VWLS (variance-weighted least squares) R2, which is obtained by using the inverse of the estimated variances in the heteroscedastic model as weights in the corresponding regression model.

uses White's heteroscedasticity-consistent standard errors. In those cases where the term of innovation technology squared is found to be non-significant, a linear relationship is estimated.

Concerning the different TAI dimensions, the results show that the creation of technology dimension only ranges in the growing part of the "U". The minimum value of this variable in the exporting country is equal to 0.078; 0.074 and 0.2 in OLS, IV and PPML, respectively. With these values, the model predicts that the greater the creation of technology, the more exports. For the second dimension, diffusion of old innovations, the results show a "U-shaped" relationship between the elasticity of exports and this dimension when applying any of the four estimation methodologies considered. This relationship becomes considerably more pronounced in the exporter's case. The minimum value of the diffusion of old innovations variable in the exporting country is 0.73; 0.82; 0.71 and 0.75 when estimating by OLS, PPML, Harvey and IV, respectively. This result indicates that there is a minimum threshold from which the more the basic technological innovation, the more the exports.

In relation to "absorptive capacity" measures, the results obtained for the diffusion of recent innovations show that there is an inverted-"U-shaped" relationship between this variable and trade according to three of the four methodologies used (the Harvey regression shows a linear relationship). The maximum of this TAI component in the exporter's case is found to range between 0.44 (PPML) and 0.68 (IV). Exporters with an intermediate achievement of diffusion of recent innovations show a higher increase in exports than countries with a lower or higher level. Otherwise for importers, the results reveal that the diffusion of recent innovations dimension mainly ranges in the growing part of the inverted-"U". Then, the more the "absorptive capacity" in the importing country, the greater the increase on trade.

Finally, the OLS, Harvey and IV regressions show that the human skills dimension in the importing country ranges in the growing part of a "U" relationship between this dimension and exports. When the PPML estimation is used however, the simulations show that this dimension in the importer's case mostly comprises the growing part of an inverted-"U-shaped" curve, where the maximum found is 0.72. These results indicate that the higher the trading partners' human skills ("absorptive capacity") are, the higher the positive effect of this variable on trade. With exporter's human skills, different results were also obtained according to the estimation technique used. Firstly, an inverted-"U-shaped" relationship was observed when using OLS (the maximum equals to 0.6), PPML (the maximum equals to 0.45) and IV (the maximum equals to 0.58), and the relationship between this variable and trade was linear when estimating by Harvey.

Figures A.1-A.5 in the Appendix show a simulation of the effect of technological innovation on export elasticities in the 13-exporter sample according to the TAI (and its components) when estimating by the IV method.

5.3. Robustness

A number of robustness checks are presented in this section. Firstly, the inverted U-Theil criterion is used to compare models with different scales in the dependent variable. Higher values of the inverted U-Theil indicate that one particular model is preferred. According to this criterion, the Harvey model estimations show a better performance than the Poisson estimations in terms of forecasting accuracy.[10]

Secondly, Equation (3) is estimated by OLS, PPML, Harvey and IV for exports of differentiated, referenced and homogeneous goods, respectively. Table 3 shows the

[10] This result has to be taken with caution because when the errors are heteroscedastic the forecasted value of log-dependent variables has to be calculated using also second order conditions. Only when the appropriate retransformation of log-dependent variables is made, the inverted U-Theil obtained for PPML can be compared with the one obtained with the other methods.

obtained results for the overall index, which show in most cases a non-linear relationship between technological innovation and trade.

Table 3. The effect of technological innovation on international trade. Sector-heterogeneity.

	Technological innovation (TAI)			
	OLS (1)	PPML (2)	Harvey (3)	IV (4)
Differentiated[11]				
Exporter's TAI/Exporter's TAI (squared)	4.45***/-3.66***	1.12***	1.98***/-1.17***	8.99***/-8.22***
Importer's TAI/Importer's TAI (squared)	0.13*/1.08***	1.88***	0.02/1.17***	0.61***/0.28**
R-squared	0.28	0.38	0.26	0.26
Number of observations	103,852	103,856	103,852	84,619
Referenced				
Exporter's TAI/Exporter's TAI (squared)	-4.59***/ 5.59***	-8.92***/10.93***	-5.39***/6.33***	-5.17***/6.19***
Importer's TAI/Importer's TAI (squared)	-0.03/0.99***	1.19***	-0.25**/1.34***	0.71***
R-squared	0.23	0.34	0.23	0.23
Number of observations	38,273	38,275	38,273	31,894
Homogeneous				
Exporter's TAI/Exporter's TAI (squared)	-5.33***/5.28***	1.93***	-8.27***/ 8.27***	-14.59***/14.77***
Importer's TAI/Importer's TAI (squared)	-0.35/1.42***	1.61***	-0.59***/1.48***	0.38/0.86*
R-squared	0.11	0.22	0.65	0.12
Number of observations	7,860	7,861	7,860	6,737

Notes: ***, **, * indicate significance at 1%, 5% and 10%, respectively. The dependent variable is the natural logarithm of exports in value (current US$). The OLS and IV estimation uses White's heteroscedasticity-consistent standard errors**.** In those cases where the term of innovation technology squared is found to be non-significant, a linear relationship is estimated.

If we take the IV results as the preferred ones, we can compare column (4) in Table 3 with column (4) in Table 2. Whereas the results concerning the effect of the importer's TAI on trade are similar for all categories of goods, the effect of the exporter's TAI is considerably different for differentiated products and the rest. For differentiated goods, the exporter's TAI shows an inverted "U-shaped" relationship, whereas for referenced-price goods and homogeneous goods, a "U-shaped" curve is found. Whereas technological improvements have a higher effect on exports of differentiated goods for intermediate levels of technological achievements, the effect on exports for referenced and homogeneous goods shows an opposite pattern, and it is found to be higher for very high levels of technological achievement. Finally, Equation (3) is also estimated for the

[11]Similar conclusions are drawn for high-technology goods, although the coefficients obtained are higher than those obtained for differentiated goods.

13-exporting country sample for both developed and developing importing countries. The obtained results show that when the importer is a developed country, technological achievement has a positive effect on exports that is magnified for higher levels of TAI. Otherwise, when the importer is a developing country, a "U-shaped" relationship between technological innovation and trade is found. The minimum for the exporter's TAI is found to be 0.45, whereas it is found to be 0.09 for the importer's TAI, thus meaning that technological improvements and the development of human skills in technologically marginalised developing countries would increase their participation in international trade.[12]

Thirdly, as an additional robustness check, we perform the same analysis for aggregated trade flows using a larger sample of countries. We use a 65-country sample which uncovers the 65-country sample selected in Márquez-Ramos (2007) by using data for 1999. The last two columns of Table 2 show the obtained results when estimating Equation (3) for both the 65-country and the 13-exporter (aggregated) samples. Results show that the coefficients obtained for technological innovation are higher than those obtained when using disaggregated data. As in the disaggregated analysis, a "U-shaped" relationship was found between exports and the diffusion of old innovations, whereas an inverted "U-shaped" relationship was seen between exports and the diffusion of recent innovations, and between exports and human skills.

Although gravity models are, in most cases, estimated using OLS, this specification does not account for the existence of causality between technological innovation and trade. Since this is a potential problem that will lead to a misspecification of the estimated model, the possible endogeneity of technological innovation in the gravity

[12] These results are available upon request from the authors.

equation is analysed in this paper. In this case, technological innovation will be correlated with the error term, while the OLS estimates will be biased and inconsistent.

In order to test the presence of endogeneity, a Hausman test is performed. The purpose of this test is to indicate whether there is correlation between technological innovation and the error term in the augmented gravity model. The null hypothesis is that there is no correlation and, therefore, that OLS provides consistent and efficient estimates. If this is true, the IV estimates should be similar to the OLS estimates. To estimate by IV, the use of a set of instrumental variables that are correlated with technological innovation in countries, but not with the error term of Equation (3), would be desirable. Average research and development expenditure (% of the GDP) in the period 1994–1998 has been selected as an instrument based on Eaton and Kortum (2002). These authors suggest that a country's level of technology is related to its stock of past research effort.

We find a significant difference between the OLS and the IV coefficients, indicating that OLS is an inconsistent estimator in the estimated model, so the IV results are preferable.

Finally, the model specification is also checked with both the disaggregated 13-exporter and the aggregated 65-country sample. A model specification error may occur when one or more relevant variables are omitted from the model, or when one or more irrelevant variables are included in the model. Model specification errors can substantially affect the estimated coefficients of regression. The linktest command in STATA is used, and the Ramsey test has been done to test for specification errors.

The linktest is based on the idea that if a regression is properly specified, then it should not be possible to find any additional independent variables that are significant except by chance. The linktest creates two new variables, a variable of the prediction (_hat) and

a variable of the square prediction (_hatsq). The model is then refitted using these new variables as predictors. The former should be significant since it is the predicted value, unlike the latter because, if the model is correctly specified, the squared predictions should not have much explanatory power.

In a first step, the linktest is calculated for the disaggregated and aggregated analysis where both the variable of prediction (_hat) and the variable of square prediction (_hatsq) are significant. In a second step, the hypothesis that the model has no omitted variables is rejected with the Ramsey RESET Test. This indicates that further research is needed to improve the specification of the estimated model.

6. Conclusions

This paper aims to provide empirical evidence on the relationship between technological innovation and international trade. Our findings indicate a positive and linear effect of technological innovation on export performance when using the Technological Achievement Index. However, the results obtained show the existence of a non-linear relationship between trade and each of the technological dimensions considered. Firstly, creation of technology fosters international trade in all countries, independently of its achievement. Secondly, a "U-shaped" relationship is observed between diffusion of old innovations and exports. Thirdly and in the case of "absorptive capacity" measures (diffusion of recent innovations and human skills), an inverted-"U-shaped" relationship with exports is observed. Fourthly, the non-linear relationship also holds in developed and developing countries, as well as in different sectors. Our results are consistent with the "learning by doing" and the "absorptive capacity" concepts.

A natural extension of this research would be 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.

7. References

- Balassa, B. (1965). "Trade Liberalization and 'Revealed' Comparative Advantage," *Manchester School* 33, 99-123.
- Bergstrand, J. H. (1985), "The gravity equation in international trade: Some microeconomic foundations and empirical evidence", *The Review of Economics and Statistics* 67(3), 474-481.
- Bergstrand, J. H. (1989), "The generalized gravity equation, monopolistic competition, and the factor-proportions theory in international trade", *The Review of Economics and Statistics* 71(1), 143-153.
- Cohen W. M and Levinthal, D. A. (1990), "Absorptive Capacity: A New Perspective on Learning and Innovation", *Administrative Science Quarterly* 35(1), 128-152.
- Deardorff, A. V. (1995), "Determinants of bilateral trade: Does gravity work in a Neo-classical word?", NBER Working Paper 5377.
- Eaton, J. and Kortum, S. (2002), "Technology, geography and trade", *Econometrica* 70(5), 1741-1779.
- Estrada, S., Heijs, J., and Buesa, M. (2006), "Innovación y comercio internacional: Una relación no lineal", Información Comercial Española 830, Los intangibles de la internacionalización empresarial, May-June.
- Fagerberg, J. (1997), "Competitiveness, scale and R&D". En: Fagerberg, J., Hansson, P., Lundberg, L. y Melchior, A., eds., *Technology and International Trade*. Cheltenham, UK, Edward Elgar: 38-55.
- Feenstra, R. C., Lipsey, R. E., Deng, H., Ma, A. C. and Mo, H. (2005), "World Trade Flows, 1962-2000". NBER-United Nations Trade Data, NBER Working Paper No. 11040.

- Fink, C., Mattoo, A. and Neagu, I. C. (2005), "Assessing the impact of communication costs on international trade," *Journal of International Economics* 67(2), 428-445.
- Harvey, A. C. (1976), "Estimating regression models with multiplicative heteroscedasticity," *Econometrica* 44, 461-465.
- INE (2006). "Lista de productos de Alta Tecnología según códigos SITC y Correspondencias con códigos CNPA-96 y PRODCOM", www.ine.es
- Jones, R.W (1970), "The Role of Technology in the Theory of International Trade", in: R. Vernon (ed.), *The Technology Factor in International Trade*, National Bureau of Economic Research, 73-94.
- Kuznets, S. (1962). "Inventive activity: Problems of definition and measurement". In: Richard R. Nelson (ed.), *The rate and direction of inventive activity: Economic and social factors*, Princeton: Princeton University Press: 19-43.
- Loungani, P., Mody, A., and Razin, A. (2002), "The Global Disconnect: The Role of Transactional Distance and Scale Economies in Gravity Equations", *Scottish Journal of Political Economy* 49(5), 526-543.
- Márquez Ramos, L. (2007), *New determinants of bilateral trade: An empirical analysis for developed and developing countries*. Doctoral Dissertation. Universitat Jaume I, Castellón. http://www.tesisenxarxa.net/TDX-0908108-140805/
- Márquez Ramos, L., Martínez Zarzoso, I., Sanjuán Lucas, E. and Suárez Burguet, C. (2007), "Efecto de las TIC sobre el comercio y el desarrollo económico: Análisis para el caso de España", Estudios de Economía Aplicada 25(1), 313-340

- Martínez Zarzoso, I. and Márquez Ramos, L. (2005), “International Trade, Technological Innovation and Income: A Gravity Model Approach”, Working Papers. Serie EC 2005-15, Instituto Valenciano de Investigaciones Económicas, S.A. (IVIE).
- Poldahl, A. and Gustavsson-Tingvall, P. (2005), “Is There Really an Inverted U-shaped Relation Between Competition and R&D?”, Working Paper Series 204, Trade Union Institute for Economic Research.
- Posner, M.V (1961), “International Trade and Technical Change,” Oxford Economic Papers, 13, 323-341
- Rauch, James E. (1999). "Networks versus markets in international trade," *Journal of International Economics* 48(1), 7-35.
- Santos-Silva, J. and Tenreyro, S. (2006), "The Log of Gravity," *The Review of*
- United Nations Development Programme (UNDP), (2001), Human Development Report, New York, Oxford University Press.
- Vernon, R (1966), “International Investment and International Trade in the Product Cycle”, *Quarterly Journal of Economics* 80, 190-207
- World Bank (2005), *World Development Indicators*, Washington, DC.

APPENDIX

Table A.1. The Technology Achievement Index.

Technological Leaders		
1	Finland	0.745
2	United States	0.733
3	Sweden	0.704
4	Japan	0.697
5	Rep. of Korea	0.664
6	Luxembourg	0.634
7	Netherlands	0.628
8	United Kingdom	0.604
9	Singapore	0.595
10	Switzerland	0.595
11	Canada	0.589
12	Australia	0.587
13	Germany	0.581
14	Norway	0.580
15	Ireland	0.564
16	Belgium	0.551
17	New Zealand	0.548
18	Denmark	0.547
19	Austria	0.542
20	Iceland	0.540
21	France	0.534
22	Israel	0.513
Potential Technological Leaders		
23	Spain	0.479
24	Italy	0.470
25	Czech Republic	0.462
26	Hungary	0.461
27	Slovenia	0.456
28	Hong Kong, China	0.453
29	Slovakia	0.444
30	Greece	0.436
31	Portugal	0.418
32	Bulgaria	0.408
33	Poland	0.402
34	Malaysia	0.392
35	Croatia	0.388
36	Cyprus	0.384
37	Mexico	0.383
38	Argentina	0.376
39	Rumania	0.365
40	Turkey	0.355
41	Costa Rica	0.354
42	Chile	0.353

Dynamic Technological Adopters		
43	Uruguay	0.339
44	South Africa	0.335
45	Thailand	0.330
46	Trinidad and Tobago	0.323
47	Panama	0.317
48	Brazil	0.306
49	China	0.293
50	Philippines	0.292
51	Bolivia	0.270
52	Colombia	0.270
53	Peru	0.265
54	Jamaica	0.256
55	Iran	0.253
56	Paraguay	0.248
57	Tunisia	0.248
58	El Salvador	0.248
59	Ecuador	0.247
60	Dominican Republic	0.238
61	Syrian Arab Republic	0.233
62	Egypt	0.228
63	Algeria	0.212
64	Zimbabwe	0.210
65	Indonesia	0.202
66	Honduras	0.199
67	Sri Lanka	0.194
68	India	0.191
Technologically Marginalised		
69	Nicaragua	0.175
70	Pakistan	0.156
71	Senegal	0.148
72	Ghana	0.127
73	Kenya	0.116
74	Nepal	0.070
75	Tanzania	0.066
76	Sudan	0.058
77	Mozambique	0.053

Notes:

Technological Leaders (above 0.5). This group includes countries with a high capability to create and sustain technological innovation.

Potential Technological Leaders (from 0.35 to 0.49). This group includes countries that have invested in all four dimensions, but have been less innovative.

Dynamic Technological Adopters (from 0.19 to 0.34). Countries in this group attempt to accomplish growth in both their technology content and their level of development.

Technologically Marginalised (below 0.19). The last group consists of marginalised countries: many African countries belong to this block. It is difficult for them to gain access even to the oldest technologies and a low technological level is associated with low income levels. The relative position is not particularly meaningful due to the lack of adequate data.

Table A.2. Variable descriptions and sources of data.

Variable	Description	Source
X_{ijk} : Exports from i to j of the commodity k	Value of exports from the 13 selected countries to 167 countries, in thousands of US dollars in the year 2000	Feenstra et al. (2005)
Y_i : Exporter's income	Exporter's GDP, PPP (current international $)	World Bank (2005)
Y_j : Importer's income	Importer's GDP, PPP (current international $)	World Bank (2005)
Adj_{ij} : Adjacency dummy	Dummy variable = 1 if the trading partners share a common border, 0 otherwise.	CEPII (2006)
$Land_i$: Landlocked dummy	Dummy variable = 1 if the exporting country is landlocked, 0 otherwise.	CEPII (2006)
$Land_j$: Landlocked dummy	Dummy variable = 1 if the importing country is landlocked, 0 otherwise.	CEPII (2006)
MERC dummy	Dummy variable = 1 if the trading partners are members of Mercosur, 0 otherwise	
NAFTA dummy	Dummy variable = 1 if the trading partners are members of NAFTA, 0 otherwise	
CAN dummy	Dummy variable = 1 if the trading partners are members of CAN, 0 otherwise	
EU dummy	Dummy variable = 1 if the trading partners are members of the European Union, 0 otherwise	
EMU dummy	Dummy variable = 1 if the trading partners are members of the Economic and Monetary Union, 0 otherwise	
ECOWAS dummy	Dummy variable = 1 if the trading partners are members of ECOWAS, 0 otherwise	
CEFTA dummy	Dummy variable = 1 if the trading partners are members of CEFTA, 0 otherwise	
$Dist_{ij}$: Distance	Great circle distances between the most important cities in trading partners	CEPII (2006) http://www.cepii.fr/anglaisgraph/bdd/distances.htm
$Lang_{ij}$: Language dummy	Dummy variable = 1 if the trading partners share the same official language, 0 otherwise.	CEPII (2006)
$Colony_{ij}$: Colony dummy	Dummy variable = 1 if the trading partners have ever had a colonial link, 0 otherwise.	CEPII (2006)
TAI_i : Exporter's TAI	Technological variable	UNDP (2001), author's calculations
TAI_j : Importer's TAI	Technological variable	UNDP (2001), author's calculations
$Tariffs_{ik}$	Effectively applied rates in sector k	WITS (2006) http://wits.worldbank.org/witsnet/StartUp/Wits_Information.aspx
TC_i: Exporter's transport costs	Transport costs (US$ per container)	Doing Business (2006)
TC_j: Importer's transport costs	Transport costs (US$ per container)	Doing Business (2006)
High-tech dummy	Dummy variable = 1 when commodity is a high-technology commodity, 0 otherwise	Jon Haveman's International Trade Data web page http://www.macalester.edu/research/economics/PAGE/HAVEMAN/Trade.Resources/TradeData.html
Hom_k dummy	Dummy variable = 1 when a commodity k is homogeneous, according to Rauch classification (1999), 0 otherwise	
Ref_k dummy	Dummy variable = 1 when a commodity k is reference-priced, according to Rauch classification (1999), 0 otherwise	Jon Haveman's International Trade Data webpage
Average R&D expenditure (% of GDP) during the period 1996-1999	TAI instrument	World Bank (2005)

Figure A.1. The TAI effect on trade elasticity. IV estimation.

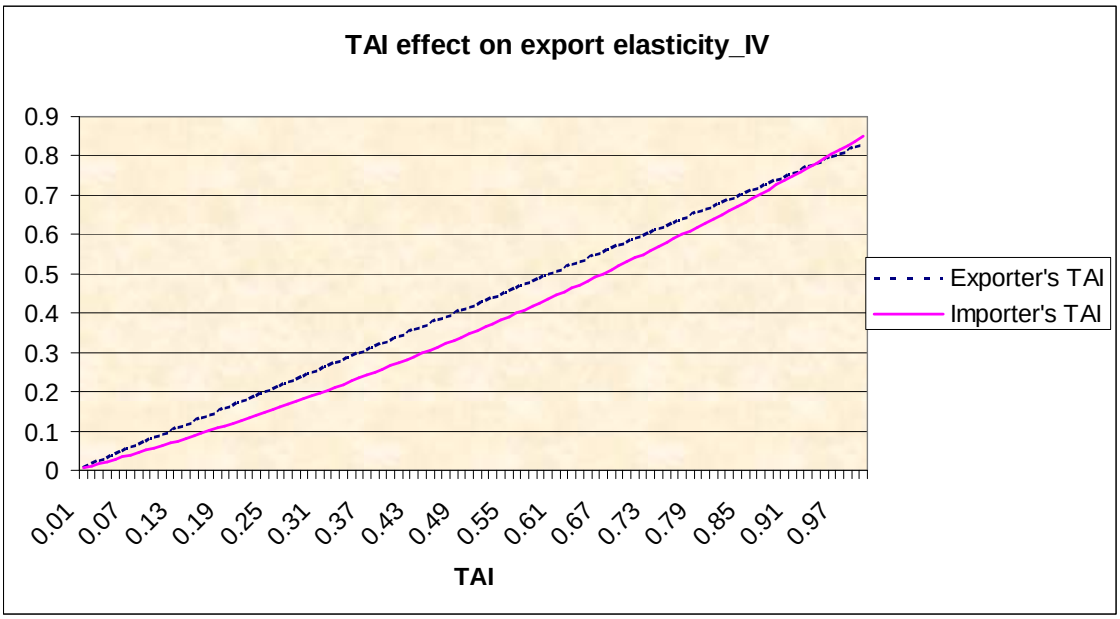

Figure A.2. The creation of technology effect on trade elasticity. IV estimation.

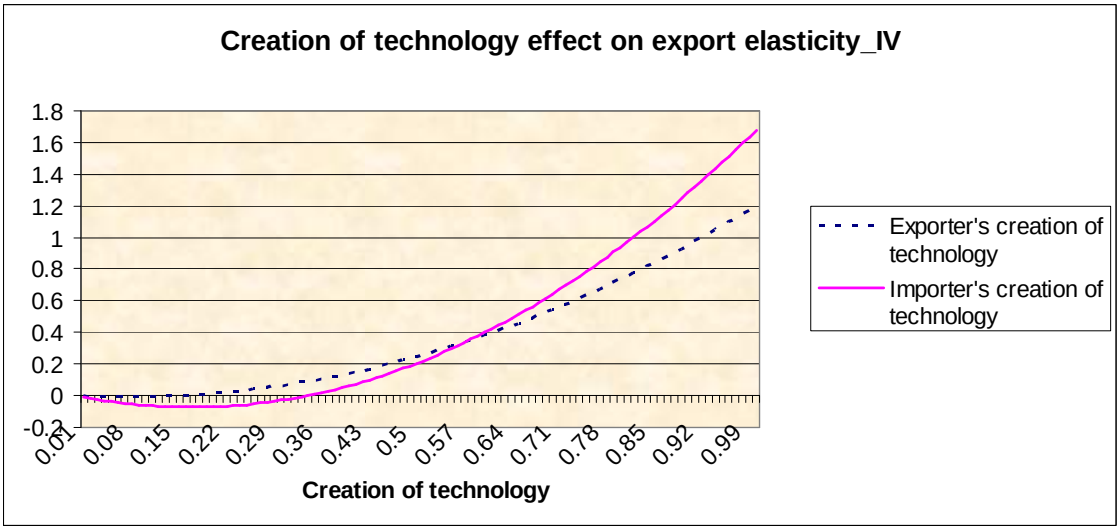

Figure A.3. The diffusion of old innovations effect on trade elasticity. IV estimation.

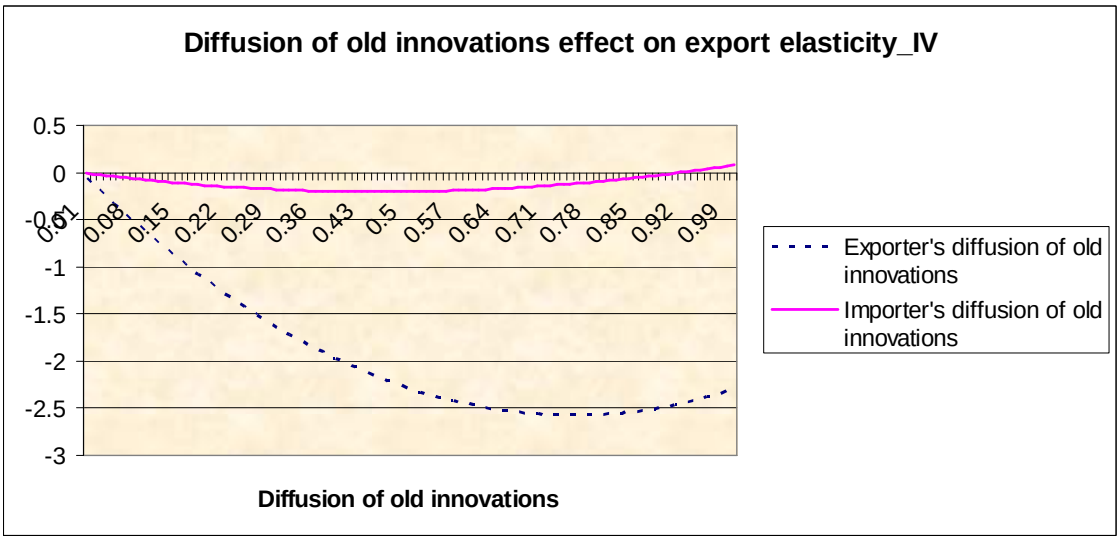

Figure A.4. The diffusion of recent innovations effect on trade elasticity. IV estimation.

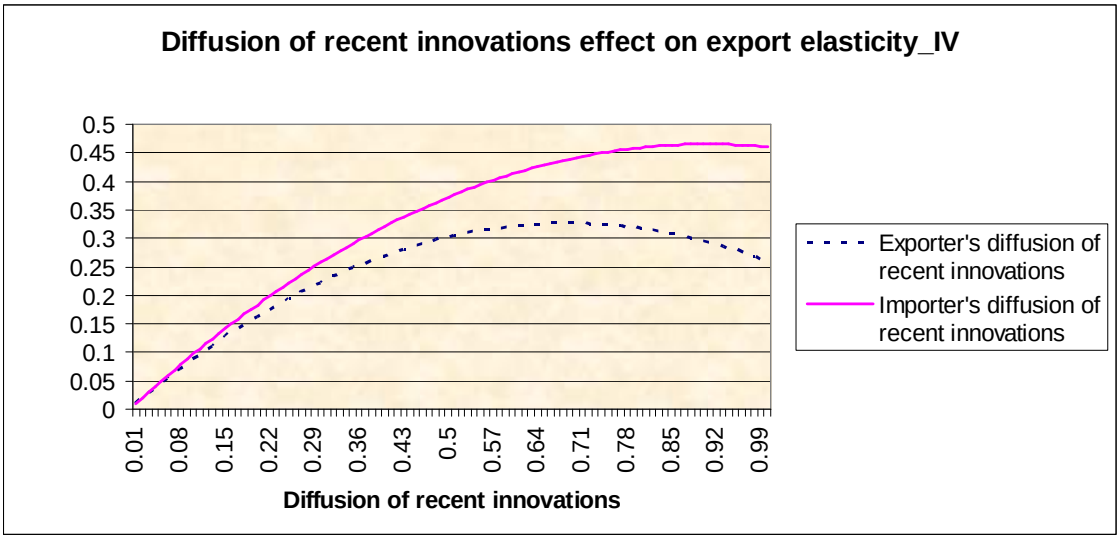
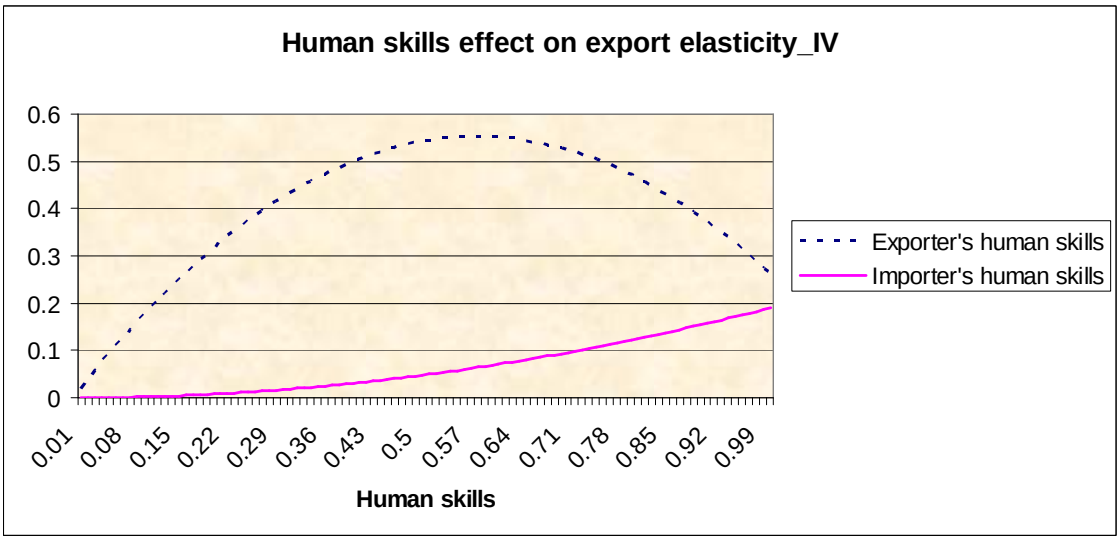
Figure A.5. The human skills effect on trade elasticity. IV estimation.