ECONOMIC GEOGRAPHY, TECHNOLOGICAL DIFFERENCES, TRADE AND INCOME: NEW EMPIRICAL EVIDENCE

By

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Abstract

In this paper we aim to investigate the effects of technological differences on international trade flows. In order to do so, we use a composite index designed to capture the performance of countries in creating and diffusing technology and in building a human skill data base. In this paper we estimate a gravity equation, augmented with technological and infrastructure variables for analysing the impact of these endowments on trade. Moreover geographical (distance, adjacency, being an island and being landlocked) and social variables (integration and preferential agreements among countries, and sharing a language) are considered. According to our results, investing in infrastructure and technology leads to improve and maintain the level of competitiveness. These variables can be considered as a barrier to trade for those countries with lower endowment levels, so investing in these variables increase the participation of poorest countries in the world economy. Geographic factors are always relevant, but technological and social factors seem to be more important for the poorest than for the richest countries. A matter of further research could be to study more deeply these aspects related to developing countries.
1. Introduction

In recent years it has been shown in the literature that economic geography determines trade, production, economic growth and welfare. Furthermore, an increasing interest has been focused in the analysis of the relationship between trade and growth, proving the relevance of international trade in economic performance and showing improvements on infrastructure endowment as an effective policy for geographically disadvantaged countries or regions.

Among several studies, Limão and Venables (2001) show how economic geography determines trade. They investigate the dependence of transport cost on geography and infrastructure and conclude that poor infrastructure and being landlocked are important determinants of transport costs, so they damage trade. Each country’s infrastructure is measured by an index which considers roads, rails and telephone lines. Bougheas et al. (1999) examine the role of infrastructure in a bilateral trade model with transport cost, which are assumed to depend inversely on the level of infrastructure. The accumulation of infrastructure is subject to the cost of technology. In order to evaluate the effect of infrastructure on trade they use an augmented gravity model by introducing two variables, the product of the stocks of public capital, as non-transport related infrastructures, and the length of motorway network, as direct measure of transport infrastructure. The authors show empirical evidence that supports the theory. Martínez-Zarzoso et al. (2003) estimate a transport cost function and a trade function using data on maritime and overland transport of the ceramic sector in Spain. They show that importer income has a positive influence in bilateral trade flows and that higher transport costs significantly deter trade. Frankel et al. (1995) use the gravity model to examine bilateral trade patterns, adding dummy variables for country pairs which share a common language and a common border. Furthermore, they include trading blocks
dummy variables which evaluate the effect of preferential agreements on trade and regionalization. Therefore, transport costs depend on geographic factors and these factors directly or indirectly influence trade, but the question that remains unanswered is: “how does technology change that relationship?” Overman et al. (2001) reinforce that geography is a major determinant of factor prices and review the empirical evidence of the determinants of trade costs and their effects on trade flows. They review a number of studies that show that trade costs is an important determinant of trade volumes, and these costs are not just a function of physical geography. A better understanding of information flows and how new technologies might possibly transform the geography of trade and production would be desirable. In this line, Freund and Weinhold (2004) find that internet stimulates trade. Their model assumes that internet reduces market-specific fixed costs of trade. The authors show how internet development explains trade growth and bilateral trade patterns. Internet also lead to greater import growth from more proximate countries, but there is not evidence in their paper that internet is altering the role of distance in trade patterns.

In this paper we aim to investigate the effects of technological differences on international trade flows. In order to do so, we use a composite index designed to capture the performance of countries in creating and diffusing technology and in building a human skill data base. The technology achievement index (TAI) used by the United Nations in their Human Development Report of 2001 could be a suitable indicator since it provides an interesting framework for this analysis and it is intended to help policy-makers to define technology strategies. It focuses on to what extent a country is participating in creating and using technology. To our knowledge, it is the first time that this index is used as an indicator for technology differences and in relation to trade flows.
In the next section we show evidence about the importance of new technologies. Section 3 presents two measures of technology existing in the literature. Section 4 presents the estimated equation and discusses the results, and Section 5 concludes.

2. The importance of new technologies

In the recent literature there have been a number of attempts to investigate the determinants of international trade. New theories emphasize endowment differences in technology as an important factor determining the characteristics and tendencies of international trade.

In this line, Filippini et al. (2003) analyse trade flows between East Asian countries in order to see their trade performance in the last 30 years. They introduce a new “distance indicator” showing that countries can be far not only from a geographical point of view. They introduce the technological distance between partners in a gravity equation illustrating the relevance of the technological gap among countries in the determination of trade flows. Freund and Weinhold (2004) show the importance of new technologies measured by internet hosts. They prove that internet stimulates trade.

Moreover, new technologies have also been related with competitiveness, giving a global approach about their state and dynamics in different countries. For example, The World Competitiveness Yearbook (2003) edited by the International Institute for Management Development (IMD) introduces four competitiveness factors: Economic Performance, Government Efficiency, Business Efficiency and Infrastructure. The breakdown of the last one includes criteria about basic infrastructure, technological infrastructure, scientific infrastructure, health and environment, and education.

The Global Competitiveness Report (2003-2004) edited by the World Economic Forum (WEF) provides the comparative strengths and weaknesses of 102 industrialized and
emerging economies. The three components of the WEF’s growth competitiveness index are: Technology, Public Institutions and Macroeconomic Environment. As the WEF states, the growth competitiveness index provides empirical valuable evidence that relates competitiveness with economic growth.

3. Measurement of technology

A great dependence on knowledge, information and high skill levels, plus an increasing need for acceding to them have made necessary the development of relevant indicators in a knowledge-based economy. The level of technology in an economy could be a good indicator to evaluate to what extent a country is well endowed with technology. There have been some attempts in current studies to measure creation, diffusion and human skills across countries, we will consider the Technology Achievement Index (TAI) by the United Nations Development Programme (UNDP) and the ArCo Technology Index introduced by Archibugi and Coco (2002).

3.1. The Technology Achievement Index (TAI)

The TAI is a new measure introduced by the UNDP in its Human Development Report of 2001. It 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. 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 quantifies some aspects of technology creation, diffusion and human skills. In order to overcome these inconveniences, the TAI is constructed using indicators of country’s achievements in four dimensions, providing a summary of a society’s technological achievements and allowing to classify countries in four groups: Leaders, Potential
Leaders, Dynamic Adopters and Marginalized. This classification could help policymakers to define technology strategies.

The four dimensions used in the construction of the TAI are: creation of technology, diffusion of recent innovations, diffusion of old innovations and human skills.

- The **creation of technology index** represents the capacity to innovate. It is relevant for all countries and constitutes the highest level of technological capacity. Two indicators are used to capture the level of innovation in a country, *number of patents granted to residents*, reflecting the current level of invention activities and representing a form of codified knowledge generated by researching in firms and organizations (Archibugi and Coco, 2002). The second indicator is *receipts of royalty and license fees from abroad*, reflecting the stock of successful innovations made in the past that are still useful.

- The **diffusion of recent innovations index** and the **diffusion of old innovations index** represent the importance that for countries have the adoption of new technologies and the participation in the Information and Knowledge Age. Since technological advance is a cumulative process, diffusion of older innovations is necessary in order to adopt later innovations. Two indicators measure the **diffusion of recent innovations, internet host**, reflecting the diffusion of the internet which allows the fastest transfer of information and an easier adaptation of firms and organizations in a changing environment, and *exports of high-technology and medium-technology products*, illustrating the level of specialization of the country in technologically intensive goods. Internet represents the newest form of technology diffusion and a key for participating in the Information and Communication Technology. Two additional indicators measure the **diffusion of old innovations, number of telephones** and **electricity**
consumption, which are important since both are needed to use new technologies and basic related activities. The electricity consumption is also a proxy for the use of machinery and equipment since most of it is generated by electric power (Archibugi and Coco, 2002). Both indicators are expressed in logarithms with an upper level (average in the countries of the OECD\(^1\), allowing to eliminate useless differences among all those countries whose telephony and electricity shares are superior to the average), since they are only relevant at earlier stages of technological advance. Expressing the measure in logarithms ensures that as the level of the index increase its contribution to the composed index decreases, allowing to discriminate among the less developed countries and showing the idea that after a certain level, neither telephones nor electricity consumption enrich the technological capacity of a country.

- The human skills index. Skills contribute to improve the technological dynamism. This index is measured by two indicators, mean years of schooling, representing that if people have basic education to develop cognitive skills, they can be users of technology, and gross tertiary science enrolment ratio, showing that as the number of inhabitants with the ability to develop skills in science, mathematics and engineering increases, grows the number of technology creators.

Scores are derived as an index relative to the maximum and minimum achieved by countries in any indicator of these dimensions. The performance of each index takes

\(^1\)OECD member countries: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, the United States. The Slovak Republic is not considered in the analysis because she joined the OECD in 2001.
a value between 0 and 1 calculated according to equation (1). The TAI is calculated as a simple average of the four dimension indices, based on the assumption that components play a comparable role in the technological achievement of a country. A second possibility to compute the composite index could be to apply equation (2), however equation (1) is preferred since the use of equation (2) imply the lose of observations and a more difficult comparison among countries due to a higher number of negative values for the dimensions and, generally, lower value for the TAI.

\[
\text{Indicator index} = \frac{(\text{actual value} - \text{observed min value})}{(\text{observed max value} - \text{observed min value})} \quad (1)
\]

\[
\text{Indicator index} = \frac{(\text{actual value} - \text{average value})}{\text{standard deviation}} \quad (2)
\]
3.2. *The ArCo Technology Index*

The ArCo is a measure for technological capabilities of a country introduced by Archibugi and Coco (2002). Their results do not differ too much from the UNDP’s study. One advantage of the ArCo index compared with the TAI index is that it is calculated for a higher number of countries and its analysis allows comparisons over time.

The authors take into account three dimensions: creation of technology, diffusion of technology and development of human skills. It is calculated as a simple average of the three dimension indices.

- The *creation of technology index* includes *number of patents* and *number of scientific articles*, 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*. Internet represents the newest form of technology diffusion, 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 natural evolution of telecommunications. Electric power consumption represents the diffusion of old innovations. Telephony and electricity indexes are expressed in natural logarithms.
- 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 human capital formation in science and technology. It is obtained by multiplying gross tertiary enrolment in the population and percentage of tertiary students in science and engineering. The 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 human skill level. The 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 ability.

The ArCo is also calculated according to equation (1).
4. Estimated equation

In order to evaluate the empirical effects of technological differences in international trade, we use a gravity model augmented with technological variables and an infrastructure index expressed in additive form using a logarithmic transformation, and adding a number of dummies. The gravity equation has been widely used to explain the structure and pattern of international trade flows. We consider that the use of the gravity model for our empirical analysis can be justified since both, theoretically and empirically. This framework is suitable to study the determinants of bilateral trade flows, as shown by the recent literature in this field (Deardorff, 1995; Bergstrand, 1985, 1989; Anderson and Wincoop, 2001), among others.

The estimated equation is,

\[ \ln X_{ij} = \alpha_0 + \alpha_1 \cdot \ln Y_i + \alpha_2 \cdot \ln Y_j + \alpha_3 \cdot \ln P_i + \alpha_4 \cdot \ln P_j + \alpha_5 \cdot Adj_{ij} + \alpha_6 \cdot Isl_i + \alpha_7 \cdot Land_{ij} + \]
\[ + \alpha_8 \cdot CACM + \alpha_9 \cdot CARIC + \alpha_{10} \cdot MERC + \alpha_{11} \cdot NAFTA + \alpha_{12} \cdot CAN + \alpha_{13} \cdot UE + \alpha_{14} \cdot \ln Dist_{ij} \]  

(3)

where \( \ln \) denotes natural logarithms.

The model is estimated with data for 62 countries in 1999. We get 3782 bilateral trade flows. We perform OLS estimation on the double log specification as given by equation (3).

\( X_{ij} \) denotes the value of exports from country \( i \) to \( j \), \( Y_i \) and \( P_i \) are income and population in the exporter’s market, \( Y_j \) and \( P_j \) are income and population in the destination market, \( Adj_{ij} \) is a dummy that takes the value 1 when countries share the same border and zero otherwise, \( Isl_i \) takes the value 1 when the exporter is an island, \( Land_{ij} \) is a dummy for landlocked countries, CACM is a dummy representing Central American Common Market countries, CARIC is a dummy representing Caribbean Community and Common Market countries, MERC is a dummy representing Mercosur countries,
NAFTA takes value 1 when countries are members of the agreement, CAN is a dummy representing Andean Nations Community members and UE takes value 1 when countries are members of the European Union. We introduce integration dummies in order to analyse the impact of trade and openness agreements on international trade. 

\( Dist_{ij} \) is distance in kilometres between the capitals of country \( i \) and \( j \), \( Lang_{ij} \) is a dummy for countries sharing the same language, \( TAI_i \) and \( TAI_j \) are technological variables measuring technology achievement in the exporter and the importer countries. Finally, \( Inf_i \) and \( Inf_j \) are infrastructure variables measuring the level of transport infrastructures in the exporter and the importer countries.

With respect to technological and infrastructure variables some additional explanations are needed. We have calculated values for TAI (the information is only available for the period 1997-2001) using the same criterions followed by United Nations Development Programme. The value for each index is the average of the indicators described in the previous section and the value for TAI is the average of all four indices. The obtained classification is slightly different to the \textit{Human Development Report} classification for 2001 because we calculate the averages for OECD member countries indicators and we use them to fill the gaps of missing data for some OECD countries, increasing the sample size. Our first results can be summarized in a ranking\(^2\) with five additional countries if we compare it with the United Nations Development Programme's ranking: Denmark, Iceland, Luxembourg, Switzerland and Turkey. These countries are OECD member countries and they increase our sample to 77 countries. The countries are classified in four blocks according to the existence of a gap among the last country of a group and the first of the next group (see UNDP, 2001 and Archibugi and Coco, 2002).

\(^2\) Appendix A. Table A.1. The three columns show the TAI ranking, the list of countries classified and the TAI value.
Infrastructure variables are calculated with the kilometres of paved roads and motorways per square kilometre, but penalizing the former. We use equation (4) to calculate the index.

\[
\text{Infrastructure variable} = \frac{(0.75 \cdot \text{paved roads (km)}) + \text{motorways (km)}}{\text{Land area (km}^2\text{)}}
\]  

(4)

We build a correlation matrix among all the explanatory variables included in the model and we do not find significant relations among them. The simple correlation coefficients are always below 60%.

Table A.1 in appendix A\(^3\) shows a summary of the data used in our analysis.

Table 1 shows our results.

In Table 1.1, Model 1 presents the OLS results for the baseline case, which excludes technological and infrastructure variables. The coefficients on income are both positive, as expected, and the income elasticities are below one for the exporter and the importer.

It takes into account the fact that higher income economies tend to be more interested in product differentiation and specialization, and therefore they trade more.

The coefficients on population are positive and significant, but since we have included countries with different levels of development we cannot observe the effect of demographic variables because it depends on the specialization of countries. Developed countries can be considered as manufacture exporters and developing industrializing countries as non-manufacture exporters. The elasticity of demographic variables might have different sign and dimension across the two groups of countries (Filippini and Molini, 2003). The coefficient on distance is negative signed, as expected, because lower distances imply lower transport cost and a higher amount of goods traded.

\(^3\) Appendix A. Table A.2. The first column lists the variables used for empirical analysis, the second column outlines a description of the variables, and the third column shows the data sources.
Model 2 shows the effect of geographical distance on bilateral trade. Distance only explains a 11% of the variability of export flows. That is the reason why we have included other geographical variables in the gravity equation. We expect that history, culture, language and social relations will also have important effects on trade.

Model 3 and 5 show the effect of technology on trade. Model 3 shows the importance of technology measured with the TAI for the exporter and the importer. The coefficient on TAI is positive and significant. The explanatory power of that variable is considerably high, compared with distance, 40% of bilateral trade is explained by $TAI_i$ and $TAI_j$.

Model 5 introduces technology measured by ArCo for the exporter and the importer. The estimated coefficient is positive and significant. The explanatory power of this variable is lower than when including the TAI index, 32% of bilateral trade is explained by $ArCo_i$ and $ArCo_j$.

Model 4 shows the effect of infrastructure on exports. The estimated coefficient is positive and significant for the exporter and the importer, and nearly 20% of bilateral trade among the countries in the sample is explained by infrastructure.

We observe a higher explanation power derived from the inclusion of technological and infrastructure variables for the exporter countries.

Model 6, in Table 1.2, shows estimation results for equation (3), where all the relevant variables are considered. Income, population, geographical distance and all the dummies are significant and show the expected sign, excluding some integration dummies. In Model 7 we exclude the non-significant dummies: NAFTA and CAN. The technological and infrastructure variables are significant and show the expected sign in Model 6 and Model 7, with an higher magnitude for the exporter countries. We find these models have high explanatory power given the high value of the $R^2$ (78.6%).
In order to consider alternative measures of technology we replace the technological variable in equation (3) by the ArCo technology index used by Archibugi and Coco (2002):

\[ \ln X_{ij} = \alpha_0 + \alpha_1 \ln Y_i + \alpha_2 \ln Y_j + \alpha_3 \ln P_i + \alpha_4 \ln P_j + \alpha_5 \cdot Adj_i + \alpha_6 \cdot Isd_i + \alpha_7 \cdot Land_j + \alpha_8 \cdot CACM + \alpha_9 \cdot CARIC + \alpha_{10} \cdot MERC + \alpha_{11} \cdot NAFTA + \alpha_{12} \cdot CAN + \alpha_{13} \cdot UE + \alpha_{14} \cdot \ln Dist_j + \alpha_{15} \cdot Lang_j + \alpha_{16} \cdot ArCo_i + \alpha_{17} \cdot ArCo_j + \alpha_{18} \cdot Inf_i + \alpha_{19} \cdot Inf_j + u_{ij} \]  

(5)

Model 8 shows estimation results for equation (5). Results are similar to those obtained in Model 6, but the magnitude of the estimated coefficient for TAI is higher than the estimated coefficient for ArCo. Both indicators are highly correlated (96%).

In Model 9 we exclude the non-significant variables: CAN and UE. We find the same \( R^2 \) than in Model 8 (77.9%). The explanatory power is lower for Models 8 and 9 than for Models 6 and 7.

In Model 10 we attempt analyse if technology has an effect on geographic distance. We use the method suggested by Freund and Weinhold (2004), creating a dummy variable, \( \text{LONGDIST} \), which takes value 1 when distance between the exporter and the importer exceeds the average distance among all countries. Then, we interact TAI and \( \text{LONGDIST} \), obtaining \( \text{LONGDIST}_i \) and \( \text{LONGDIST}_j \). These coefficients are positive but non-significant.

As we compose \( \text{LONGDIST}_i \) and \( \text{LONGDIST}_j \) with \( \text{TAI}_i \) and \( \text{TAI}_j \), we use ArCo instead of TAI in Model 11 for analysing the effect of the knowledge-based economies on trade. Our results offer evidence that Information and Knowledge Age has altered the effect of distance on trade.

In order to understand if there exist a differential behaviour for groups of countries, we divide our sample in several groups according to the level of development. The effect of demographic variables depends on the specialization of countries, according to Filippini
and Molini (2003). They consider two commodity groups and classify developed countries as exporters of manufactured goods and developing countries as importers.

Our classification is composed by three groups: Countries with high GDP per capita, medium GDP per capita and low GDP per capita. We order countries from higher to lower income levels, then we compose an upper level of GDP calculating the average of the first half of the sample, and an inferior level calculating the average of the second. We can study the evolution and convergence of the groups if we calculate the GDP per capita average for countries in each group annually (Figure 2 in Appendix B).

Model 12 and 13 in Table 1.3 estimate equation (3) for countries with high and low GDP per capita respectively. We just consider two groups instead of three in order to have a higher contrast between them.

In the model used for the richest countries (Model 12) importer’s income, adjacency, island and landlocked dummies, distance, exporter’s TAI and exporter’s infrastructure are significant at 10%. Demographic variables (population of the countries) are non-significant, as Filippini and Molini (2003) explain⁴, “in developed countries the demographic transition is over, consequently the trend of population growth is stable and almost close to 0 (…) we expect a non-significant or negative coefficient”.

Variables in Model 12 explain 88% of the variability in exports.

In the model used for the poorest countries (Model 13) exporter’s and importer’s population, landlocked dummy, geographical distance, language dummy, exporter’s and importer’s TAI seem to be significant. Demographic variables for exporters have a positive relation with trade, indicating that more availability of cheap labour force for industries in developing countries foster trade.

Finally, technological and infrastructure variables seem to be non-significant for importers when trade is among the richest countries, and only technological variables are significant for the poorest countries. An explanation could be the non-arrival at a minimum level of transport infrastructure in developing countries. Technology and infrastructure can be considered as a barrier to trade for those countries with lower endowment levels, so investing in these variables could foster international trade and increase the participation of poorest countries in a more and more globalized and integrated world.

5. Conclusion

In this paper we estimate a gravity equation augmented with technological and infrastructure variables in order to analyse the impact of these endowments on trade. Moreover geographical (distance, adjacency, being an island and being landlocked) and social variables (integration and preferential agreements among countries, and sharing a language) are considered.

Several authors have shown that economic geography determines trade flows. Others have studied the importance of infrastructure endowments in countries and transport costs in international trade. However a better understanding of information flows and technological change is needed because they can transform the geography of trade and production.

In our model, all variables included are expected signed and significant, excluding some integration variables. We show that distance have a considerably low explanatory power on trade compared with infrastructure and technology. Importers technology has a lower effect on trade than exporters technology, a higher technology endowment in an exporter country leads to greater exports.
According to our results, investing in infrastructure and technology leads to improve and maintain the level of competitiveness. These variables can be considered as a barrier to trade for those countries with lower endowment levels, so investing in these variables increase the participation of poorest countries in the world economy.

We also attempt to analyse whether technology has effect on geographic distance in a more globalized and integrated world. We support the evidence that Information and Knowledge Age has altered the effect of distance on trade.

Finally, in order to infer if there is a differential behaviour among countries we divide our sample in three groups according to the level of wealth. We cannot observe a convergence trend in our sample. For the richest countries, variables included in our model explain a higher variability on trade flows than for the poorest countries. Geographic factors are always relevant, but technological and social factors seem to be more important for the poorest than for the richest countries. A matter of further research could be to study more deeply these aspects related to developing countries.
Bibliography


Statistics Canada (1999), *World Trade Analyzer*.


World Bank (2001), *World Development Indicators*. 
### Table 1. Determinants of international trade

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
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</tr>
<tr>
<td>Importer’s TAI</td>
<td>-</td>
<td>7.21***</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(29.12)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exporter’s ArCo</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>7.83***</td>
<td>5.91***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(31.77)</td>
<td>(24.38)</td>
</tr>
<tr>
<td>Importer’s ArCo</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.5***</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(21.41)</td>
<td></td>
</tr>
<tr>
<td>Exporter’s infrastructure</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.23***</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(17.24)</td>
<td></td>
</tr>
<tr>
<td>Importer’s infrastructure</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.407</td>
<td>0.113</td>
<td>0.401</td>
<td>0.187</td>
<td>0.323</td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>0.406</td>
<td>0.113</td>
<td>0.4</td>
<td>0.187</td>
<td>0.322</td>
</tr>
<tr>
<td>S.E. of regression</td>
<td>2.511</td>
<td>3.069</td>
<td>2.525</td>
<td>2.939</td>
<td>2.683</td>
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<td>3126</td>
<td>3126</td>
<td>3126</td>
<td>3126</td>
</tr>
</tbody>
</table>

**Table 1.1.** Determinants of international trade. Baseline model and contribution of specific variables.

Note: ***, **, *,  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$). Income, population and distance are also in natural logarithms. The estimation uses white’s heteroscedasticity-consistent standard errors.
Table 1.2. Determinants of international trade. Augmented gravity model. Note: ***, **, * indicate significance at 1%, 5% and 10%, respectively. T-statistics are in brackets. The dependent variable is the natural logarithm of...
exports in value (current US$). Income, population and distance are also in natural logarithms. The estimation uses white’s heteroscedasticity-consistent standard errors.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model 12</th>
<th>Model 13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant term</td>
<td>-31.11***</td>
<td>-11.75***</td>
</tr>
<tr>
<td></td>
<td>(-2.82)</td>
<td>(-3.77)</td>
</tr>
<tr>
<td>Exporter’s income</td>
<td>1.03</td>
<td>-0.04</td>
</tr>
<tr>
<td></td>
<td>(1.42)</td>
<td>(-0.48)</td>
</tr>
<tr>
<td>Importer’s income</td>
<td>1.29*</td>
<td>-0.06</td>
</tr>
<tr>
<td></td>
<td>(1.78)</td>
<td>(-1.62)</td>
</tr>
<tr>
<td>Exporter’s population</td>
<td>-0.23</td>
<td>1.23***</td>
</tr>
<tr>
<td></td>
<td>(-0.31)</td>
<td>(8.31)</td>
</tr>
<tr>
<td>Importer’s population</td>
<td>-0.48</td>
<td>0.54***</td>
</tr>
<tr>
<td></td>
<td>(-0.66)</td>
<td>(5.35)</td>
</tr>
<tr>
<td>Adjacency dummy</td>
<td>0.47*</td>
<td>0.41</td>
</tr>
<tr>
<td></td>
<td>(1.92)</td>
<td>(0.65)</td>
</tr>
<tr>
<td>Island dummy</td>
<td>0.27*</td>
<td>3.39</td>
</tr>
<tr>
<td></td>
<td>(1.91)</td>
<td>(0.75)</td>
</tr>
<tr>
<td>Landlocked dummy</td>
<td>-0.37***</td>
<td>-1.13***</td>
</tr>
<tr>
<td></td>
<td>(-2.79)</td>
<td>(-2.81)</td>
</tr>
<tr>
<td>Distance</td>
<td>-0.93***</td>
<td>-1.34***</td>
</tr>
<tr>
<td></td>
<td>(-12.13)</td>
<td>(-6.56)</td>
</tr>
<tr>
<td>Language dummy</td>
<td>-0.07</td>
<td>1.16***</td>
</tr>
<tr>
<td></td>
<td>(-0.5)</td>
<td>(2.87)</td>
</tr>
<tr>
<td>Exporter’s TAI</td>
<td>2.41**</td>
<td>5.15**</td>
</tr>
<tr>
<td></td>
<td>(2.32)</td>
<td>(2.07)</td>
</tr>
<tr>
<td>Importer’s TAI</td>
<td>1.08</td>
<td>6.7***</td>
</tr>
<tr>
<td></td>
<td>(1.04)</td>
<td>(2.8)</td>
</tr>
<tr>
<td>Exporter’s infrastructure</td>
<td>0.22**</td>
<td>-2.95</td>
</tr>
<tr>
<td></td>
<td>(2.58)</td>
<td>(-0.6)</td>
</tr>
<tr>
<td>Importer’s infrastructure</td>
<td>-0.01</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td>(-0.14)</td>
<td>(0.14)</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.886</td>
<td>0.696</td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>0.877</td>
<td>0.667</td>
</tr>
<tr>
<td>S.E. of regression</td>
<td>0.719</td>
<td>1.755</td>
</tr>
<tr>
<td>Number of observations</td>
<td>182</td>
<td>150</td>
</tr>
</tbody>
</table>

*Table 1.3. Determinants of international trade. Estimation results for high and low income countries.*

Note: ***, **, *, 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$). Income, population and distance are also in natural logarithms. The estimation uses white’s heteroscedasticity-consistent standard errors.
# APPENDIX A

Table A.1. The Technology Achievement Index

<table>
<thead>
<tr>
<th>Leaders</th>
<th>Dynamic Adopters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Finland</td>
</tr>
<tr>
<td>2</td>
<td>United States</td>
</tr>
<tr>
<td>3</td>
<td>Sweden</td>
</tr>
<tr>
<td>4</td>
<td>Japan</td>
</tr>
<tr>
<td>5</td>
<td>Rep. of Korea</td>
</tr>
<tr>
<td>6</td>
<td>Luxembourg</td>
</tr>
<tr>
<td>7</td>
<td>Netherlands</td>
</tr>
<tr>
<td>8</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>9</td>
<td>Singapore</td>
</tr>
<tr>
<td>10</td>
<td>Switzerland</td>
</tr>
<tr>
<td>11</td>
<td>Canada</td>
</tr>
<tr>
<td>12</td>
<td>Australia</td>
</tr>
<tr>
<td>13</td>
<td>Germany</td>
</tr>
<tr>
<td>14</td>
<td>Norway</td>
</tr>
<tr>
<td>15</td>
<td>Ireland</td>
</tr>
<tr>
<td>16</td>
<td>Belgium</td>
</tr>
<tr>
<td>17</td>
<td>New Zealand</td>
</tr>
<tr>
<td>18</td>
<td>Denmark</td>
</tr>
<tr>
<td>19</td>
<td>Austria</td>
</tr>
<tr>
<td>20</td>
<td>Iceland</td>
</tr>
<tr>
<td>21</td>
<td>France</td>
</tr>
<tr>
<td>22</td>
<td>Israel</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Spain</td>
</tr>
<tr>
<td>24</td>
<td>Italy</td>
</tr>
<tr>
<td>25</td>
<td>Czech Republic</td>
</tr>
<tr>
<td>26</td>
<td>Hungary</td>
</tr>
<tr>
<td>27</td>
<td>Slovenia</td>
</tr>
<tr>
<td>28</td>
<td>Hong Kong,China</td>
</tr>
<tr>
<td>29</td>
<td>Slovakia</td>
</tr>
<tr>
<td>30</td>
<td>Greece</td>
</tr>
<tr>
<td>31</td>
<td>Portugal</td>
</tr>
<tr>
<td>32</td>
<td>Bulgaria</td>
</tr>
<tr>
<td>33</td>
<td>Poland</td>
</tr>
<tr>
<td>34</td>
<td>Malaysia</td>
</tr>
<tr>
<td>35</td>
<td>Croatia</td>
</tr>
<tr>
<td>36</td>
<td>Cyprus</td>
</tr>
<tr>
<td>37</td>
<td>Mexico</td>
</tr>
<tr>
<td>38</td>
<td>Argentina</td>
</tr>
<tr>
<td>39</td>
<td>Romania</td>
</tr>
<tr>
<td>40</td>
<td>Turkey</td>
</tr>
<tr>
<td>41</td>
<td>Costa Rica</td>
</tr>
<tr>
<td>42</td>
<td>Chile</td>
</tr>
</tbody>
</table>
Notes:

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Leaders (above 0.5).</strong></td>
<td>That group includes countries with high capability to create and sustain</td>
</tr>
<tr>
<td></td>
<td>technological innovation.</td>
</tr>
<tr>
<td><strong>Potential Leaders (from 0.35 to 0.49).</strong></td>
<td>That group includes countries who have invested in all four dimensions, but they have been less innovative.</td>
</tr>
<tr>
<td><strong>Dynamic Adopters (from 0.19 to 0.34).</strong></td>
<td>Countries in this group try to growth in their technology content and in their level of development.</td>
</tr>
<tr>
<td><strong>Marginalized (below 0.19).</strong></td>
<td>The last group is composed by marginalized countries, many African countries belong to this block. They have a hard access even to the oldest technologies and a low technological level is associated to low income levels. The relative position is not particularly meaningful due to the lack of adequate data.</td>
</tr>
</tbody>
</table>
### Table A.2: Variable descriptions and sources of data

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_{ij}$: Exports from i to j</td>
<td>Nominal value of bilateral exports</td>
<td>Statistics Canada (1999)</td>
</tr>
<tr>
<td>$Y_i$: Exporter’s income</td>
<td>Exporter’s GDP, PPP (current international $)</td>
<td>World Bank (2001)</td>
</tr>
<tr>
<td>$Y_j$: Importer’s income</td>
<td>Importer’s GDP, PPP (current international $)</td>
<td>World Bank (2001)</td>
</tr>
<tr>
<td>$P_i$: Exporter’s population</td>
<td>Total population in the exporter’s market</td>
<td>World Bank (2001)</td>
</tr>
<tr>
<td>$P_j$: Importer’s population</td>
<td>Total population in the importer’s market</td>
<td>World Bank (2001)</td>
</tr>
<tr>
<td>$Adj_{ij}$: Adjacency dummy</td>
<td>Dummy variable = 1 if the trading partners share a border, 0 otherwise</td>
<td>CIA (2003)</td>
</tr>
<tr>
<td>$Isl_i$: Island dummy</td>
<td>Dummy variable = 1 if the exporter country is an island, 0 otherwise</td>
<td>CIA (2003)</td>
</tr>
<tr>
<td>$Land_{ij}$: Landlocked dummy</td>
<td>Dummy variable = 1 if the country is landlocked, 0 otherwise</td>
<td>CIA (2003)</td>
</tr>
<tr>
<td>CACM dummy</td>
<td>Dummy variable = 1 if the trading partners are members of CACM, 0 otherwise</td>
<td>Foreign Trade Information System <a href="https://www.sice.oas.org/">www.sice.oas.org/</a></td>
</tr>
<tr>
<td>CARICOM dummy</td>
<td>Dummy variable = 1 if the trading partners are members of CARICOM, 0 otherwise</td>
<td>Foreign Trade Information System <a href="https://www.sice.oas.org/">www.sice.oas.org/</a></td>
</tr>
<tr>
<td>MERCOSUR dummy</td>
<td>Dummy variable = 1 if the trading partners are members of MERCOSUR, 0 otherwise</td>
<td>Foreign Trade Information System <a href="https://www.sice.oas.org/">www.sice.oas.org/</a></td>
</tr>
<tr>
<td>NAFTA dummy</td>
<td>Dummy variable = 1 if the trading partners are members of NAFTA, 0 otherwise</td>
<td>Foreign Trade Information System <a href="https://www.sice.oas.org/">www.sice.oas.org/</a></td>
</tr>
<tr>
<td>CAN dummy</td>
<td>Dummy variable = 1 if the trading partners are members of CAN, 0 otherwise</td>
<td>Foreign Trade Information System <a href="https://www.sice.oas.org/">www.sice.oas.org/</a></td>
</tr>
<tr>
<td>UE dummy</td>
<td>Dummy variable = 1 if the trading partners are members of European Union, 0 otherwise</td>
<td><a href="http://www.wcrl.ars.usda.gov/cec/java/lat-long.htm">www.wcrl.ars.usda.gov/cec/java/lat-long.htm</a></td>
</tr>
<tr>
<td>$Dist_{ij}$: Distance</td>
<td>Great circle distances between country capitals of trading partners (km)</td>
<td><a href="http://www.wcrl.ars.usda.gov/cec/java/lat-long.htm">www.wcrl.ars.usda.gov/cec/java/lat-long.htm</a></td>
</tr>
<tr>
<td>$Lang_{ij}$: Language dummy</td>
<td>Dummy variable = 1 if the trading partners share a same official language, 0 otherwise.</td>
<td>CIA (2003)</td>
</tr>
<tr>
<td>$TAI_i$: Exporter’s TAI</td>
<td>Technological variable</td>
<td>UNDP (2001), author’s calculations</td>
</tr>
<tr>
<td>$TAI_j$: Importer’s TAI</td>
<td>Technological variable</td>
<td>UNDP (2001), author’s calculations</td>
</tr>
<tr>
<td>$ArCo_i$: Exporter’s ArCo</td>
<td>Technological variable</td>
<td>Archibugi and Coco (2002)</td>
</tr>
<tr>
<td>$ArCo_j$: Importer’s ArCo</td>
<td>Technological variable</td>
<td>Archibugi and Coco (2002)</td>
</tr>
<tr>
<td>$Inf_i$: Exporter’s infrastructure</td>
<td>Infrastructure variable</td>
<td>CIA (2003), authors’ calculations</td>
</tr>
<tr>
<td>$Inf_j$: Importer’s infrastructure</td>
<td>Infrastructure variable</td>
<td>CIA (2003), authors’ calculations</td>
</tr>
</tbody>
</table>

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

Figure 1: Countries utilized in the analysis

Leaders: Finland, United States, Sweden, Japan, Rep. of Korea, Belgium-Luxembourg, Netherlands, United Kingdom, Singapore, Switzerland, Canada, Australia, Germany, Norway, Ireland, Denmark, Austria, Iceland, France, Israel.

Potential Leaders: Spain, Italy, Czech Republic, Hong Kong, Slovakia, Greece, Portugal, Bulgaria, Poland, Croatia, Cyprus, Mexico, Argentina, Turkey, Costa Rica, Chile.

Dynamic Adopters: Uruguay, South Africa, Trinidad and Tobago, Panama, Brazil, China, Colombia, Peru, Jamaica, Paraguay, El Salvador, Dominican Republic, Syrian Arab Republic, Egypt, Algeria, Honduras, India.

Marginalized: Nicaragua, Pakistan, Senegal, Ghana, Kenya, Nepal, Tanzania, Sudan, Mozambique.
Figure 2: Groups of countries


Countries with high GDP: Belgium-Luxembourg, United States, Norway, Iceland, Switzerland, Canada, Ireland, Denmark, Austria, Japan, Australia, Netherlands, Germany, Finland.

Countries with medium GDP: France, Sweden, Italy, United Kingdom, Hong Kong, Singapore, Cyprus, Israel, Spain, Portugal, Republic of Korea, Greece, Czech Republic, Argentina, Slovak Republic, South Africa, Uruguay, Costa Rica, Chile, Poland, Mexico, Trinidad and Tobago, Croatia, Brazil, Turkey, Panama, Colombia, Dominican Republic, Bulgaria, Algeria.

Countries with low GDP: Peru, Syrian Arab Republic, Paraguay, El Salvador, China, Jamaica, Egypt, Honduras, Nicaragua, India, Ghana, Pakistan, Sudan, Senegal, Nepal, Kenya, Mozambique, Tanzania.

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