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 transport infrastructure variables 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. According to our results, investing in transport 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, therefore investing in these variables increase the participation of the poorest countries in the world economy. Geographical factors are always relevant, but technological and social factors seem to be more important for the poorest than for the richest countries *(F14, O30).*

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 on the analysis of the relationship between trade and growth, proving the relevance of international trade on economic performance and showing improvements on infrastructure endowment as an effective policy for geographically disadvantaged countries or regions.

In the recent literature several studies have appeared that relate trade with geography, infrastructure, cultural and social factors by gravity equations. Among them, Limâo and Venables (2001) show how economic geography determines trade. They investigate the dependence of transport cost on geography and infrastructure and show that poor infrastructure damages trade. They measure countries' infrastructure by an index constructed from four variables: kilometres of road, kilometres of paved road, kilometres of rail (each given per square kilometre of country area) and telephone mainlines per person. Bougheas *et al.* (1999) examine the role of infrastructure in a bilateral trade model with transport costs, which are assumed to depend inversely on the level of infrastructure. They evaluate the effect of public capital, which includes non-transport related infrastructure and a direct measure of transport infrastructure, the length of the motorway network. Both variables are expected to be positive, since a higher level of public infrastructure should reduce transport costs, which in turn facilitates trade. 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 on bilateral trade flows and that higher transport costs significantly deter trade. Moreover, they calculate an infrastructure index constructed by taking the mean over four variables: kilometres of paved road, kilometres of rail (each given per square kilometre of country area) and telephone mainlines per person. This index is expected to have a negative sign and is significant, which therefore shows that infrastructure is an important determinant of transport costs.

With regard to cultural and social factors, Frankel *et al.* (1995) use a gravity model to explain intra-regional trade, which could be explained by the proximity between two commercial partners, the sizes and economic sizes of the countries and whether they share a common border or a common language. Their results show that some degree of preferences would be a good thing, but free trade areas would represent an excessive degree of regionalisation of world trade. Frankel *et al.* (1996) state that the desirability of regional trading arrangements depends on whether the extent of regionalisation exceeds an optimal level that is determined by the transportation costs between regions. When the authors introduce shipping costs between continents as a fraction of the value of the goods shipped, they found that free trading arrangements are detrimental (over a moderate range of parameter values), but generalising to preferential trading arrangements, they find that it is beneficial for continental neighbours until preferences exceed an optimal level and enter the zone of negative returns to regionalisation.

We learn from the abovementioned studies that transport costs depend on geographical factors and these factors directly or indirectly influence trade, however there is an interesting question that remains unanswered: "how does technology change this relationship?". Overman *et al.* (2001) reinforce the idea that geography is a major determinant of the 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 are an important determinant of trade volumes, and these costs are not just a function of physical geography. The authors point out that a better understanding of information flows and how new technologies might possibly transform the geography of trade and production would be desirable.

To our knowledge, there are only a few recent studies that relate trade with informational flows and new technologies (Filippini and Molini (2003), Freund and Weinhold (2004)). In order to shed some light on this field of research, in this paper we aim to investigate the effects of technological differences on international trade flows. In order to do so, in our empirical framework we utilise 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 because it provides an interesting framework for this analysis and it is intended to help policy-makers to define technology strategies. It focuses on the extent to which a country is participating in the creation and use of 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 some measures of technology existing in the literature. Section 4 presents the estimated equation and discusses the results. Finally, 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 (Krugman (1979), Grossman and Helpman (1990), (1991)). However, Grossman and Helpman (1990) point out that "we need to learn much more about the mechanisms by which knowledge and technology diffuse across international borders"[1].

From an empirical point of view, there are two investigations closely related to our work. One of these is Filippini and Molini (2003), where trade flows among East Asian countries are examined in order to analyse their trade performance in the last 30 years. They introduce a new "distance indicator" showing that countries can be a long way from each other, not only from a geographical point of view, but also from a technological perspective. 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) find that the Internet stimulates trade. Their model assumes that the Internet reduces market-specific fixed costs of trade. The authors show how the development of the Internet explains trade growth and bilateral trade patterns by time-series and cross-sectional variation in the data. The Internet leads to greater import growth from countries that are closer to each other, but there is no evidence in their paper that the Internet is altering the role of distance in trade patterns. They also present the results of a modified gravity equation to test whether an impact of the Internet on trade patterns exists in the cross-section as well as in the time series. They show the importance of new technologies on trade as measured by Internet hosts.

New technologies have also been related with competitiveness, thus giving a global approach to 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

[1] Grossman and Helpman, 1990, page 91.

last component 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 industrialised 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 to have access to them calls for the development of relevant indicators in a knowledge-based economy. Some attempts have been made in current studies to measure creation, diffusion and human skills across countries, and we therefore present a table including some indicators existing in the literature that attempt to proxy the endowment of countries in information technology by composite indexes (Table A) and a table including some variables which have been used as proxies in the literature to analyse the effect of information technology and innovation on economy (Table B).

Table A. Measurement of information technology by composite indexes.

Variable	Description	Source
ArCo	This index takes into account three dimensions: **Creation of technology** *(number of patents*, *number of scientific articles)*, **diffusion of technology** *(Internet penetration*, *telephone penetration*, *electricity consumption*) and **development of human skills** *(gross tertiary science and engineering enrolment*, *mean years of schooling*, *adult literacy rate)*	Archibugi and Coco (2002)
ITR	The "Internet Traffic Report" monitors the flow of data around the world. It displays a value between zero and 100. Higher values indicate faster and more reliable connections.	ITR: www.internettrafficreport.com
ICT	The index of ICT diffusion is made up of two dimensions: **Connectivity** *(Internet hosts, PCs, telephone mainlines and cellular subscribers)* and **access** *(Internet users, literacy, GDP per capita and cost of a local call).* Moreover, a third dimension (**policy**) is presented separately.	Phillipa Biggs, UNCTAD (2003)
TAI	The "Technology Achievement Index" is made up of four dimensions: **Creation of technology** *(number of patents granted to residents, receipts of royalty and license fees from abroad)*, **diffusion of recent innovations** *(Internet host, exports of high-technology and medium-technology products)*, **diffusion of old innovations** *(number of telephones, electricity consumption*) and **human skills** *(mean years of schooling*, *gross tertiary science enrolment ratio).*	UNDP (2001)
NRI	The "Network Readiness Index" measures the degree of preparation of a nation or community to participate in and benefit from Information and Communication Technology (ICT) developments. It is made up of three dimensions: **Environment** offered by a country or community, the **readiness** of the community's key stakeholders and the **usage** of ICT.	WEF *et al.* (2004)

Table B. Variables which analyse the effect of information technology and innovation on economy.

Variable	Description	Source
Foreign R&D capital	R&D *spillovers*	Bayoumi *et al.* (1999)
Proportion of non-managers using computers	Measures the impact of computers on productivity	Black and Lynch (2004)
Expenditure on R&D	Indicators of R&D and innovation	Caballero *et al.* (2002)
Workers in R&D and innovation sectors	Indicators of R&D and innovation	Caballero *et al.* (2002)
Number of researchers	Indicators of R&D and innovation	Caballero *et al.* (2002)
Expenditure on innovation per worker	Indicators of innovation	Calvo (2002)
Foreign R&D capital stock	R&D *spillovers*	Coe and Helpman (1995)
Foreign R&D capital stock	R&D *spillovers*	Coe *et al.* (1997)
$T_i = \alpha_0 R_i^{\alpha_R} e^{-\alpha_H / H_i} e^{\tau_i}$ [2]	Level of technology	Eaton and Kortum (1997)
Internet *hosts*	Measures the Internet development in a country	Freund and Weinhold (2004)
Telecommunications and Internet consumption	Indicators of ICT	García Castillejo (2002)
Average number of patents *per capita*	Proxy of innovative output	Moreno *et al*. (2004)
Expenditure on R&D	Indicators of R&D	Sánchez (dir), (2000)
Inputs assigned for basic research	Indicators of R&D	Sánchez (dir), (2000)
Expenditure on Information and Communication Technology (ICT)	Indicators of ICT	Sánchez, (dir), (2000)
Equipment investment per PEP (person engaged in production)	Proxy of technological change	Wolff (2002)

In this paper we will consider the technology achievement index (TAI) developed by the United Nations Development Programme (UNDP, 2001) and the ArCo Technology Index introduced by Archibugi and Coco (2002).

<u>*The technology achievement index (TAI)*</u>

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. A nation's technological achievements are very complex and therefore it is

[2] The authors suggest that a country's level of technology T is related to its stock of past research effort and that a higher stock of human capital allows a country to absorb more ideas from abroad. In this equation, R_i is cumulative research investment in country i, H_i is the average years of education of a worker, and τ_i represents unobserved determinants of technology in country i. The functional form of the human capital effect implies that the fraction of world knowledge that a country exploits rises with H.

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 a country's achievements in four dimensions, thus providing a summary of a society's technological achievements and allowing countries to be classified in four groups: Leaders, Potential Leaders, Dynamic Adopters and Marginalised. This classification could help policy-makers 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 <u>*creation of technology index*</u> 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*, which reflects the current level of invention activities and representing a form of codified knowledge generated by researching in firms and organisations (Archibugi and Coco, 2002). The second indicator is *receipts of royalty and license fees from abroad*, which indicates the stock of successful innovations made in the past that are still useful.
- The <u>*diffusion of recent innovations index*</u> and the <u>*diffusion of old innovations index*</u> represent the importance that the adoption of new technologies and the participation in the information and knowledge age are for countries. 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*. The first is *Internet hosts* reflects the diffusion of the Internet, which allows the fastest transfer of information and an easier adaptation of firms and organisations in a changing environment; the second is

exports of high-technology and medium-technology products, illustrating the level of specialisation of the country in technologically intensive goods. The Internet represents the newest form of technology diffusion and a key for participating in Information and Communication Technology. Two additional indicators measure the *diffusion of old innovations*, namely, *number of telephones* and *electricity consumption*, which are important since both are needed to be able to use new technologies and basic related activities. 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 OECD[3] countries, allowing the elimination of useless differences among all countries whose telephony and electricity shares are above 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 increases its contribution to the composed index decreases, thus allowing us to discriminate among the less developed countries and showing the idea that, beyond a certain level, neither telephones nor electricity consumption enrich the technological capacity of a country.

- The <u>*human skills index*</u>. Skills contribute to improve technological dynamism. This index is measured by two indicators, *mean years of schooling*, representing the fact that if people have basic education to develop cognitive skills, they can

[3]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 it joined the OECD in 2001.

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, the number of technology creators also grows.

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 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) implies the loss of observations and a more difficult comparison among countries due to a higher number of negative values for the dimensions and, generally, a lower value for the TAI.

$$Indicator\ \ index = \frac{(actual\,value - observed\ \min value)}{(observed \max\ value - observed \min value)} \qquad (1)$$

$$\boldsymbol{Indicator\ \ index} = \frac{(\boldsymbol{actual\,value - average\,value})}{\boldsymbol{s}\tan\boldsymbol{dar\,deviation}} \qquad (2)$$

The ArCo Technology Index

The ArCo is a measure of technological capabilities of a country introduced by Archibugi and Coco (2002). Their results do not differ too much from the UNDP 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 three dimensions take into account: 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.* The Internet represents the newest form of technology diffusion, and its penetration is measured by the data on users. *Telephone penetration* includes the number of telephones mainlines, which are a fundamental infrastructure for economic and social life, and the number of mobile phones, which are the 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 formation of human

capital in science and technology. It is obtained by multiplying gross tertiary enrolment in the population and the percentage of tertiary students in science and engineering. 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. *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 on international trade, we use a gravity model augmented with technological variables and an infrastructure index expressed in additive form using a logarithmic transformation, and a number of dummies are also added. The gravity equation has been widely used to explain the structure and pattern of international trade flows. This framework is suited to the study of the determinants of bilateral trade flows, as shown by the recent literature in this field (Iwuagwu-Oguledo and Macphee, 1994; Deardorff, 1995; Bergstrand, 1985, 1989; Anderson and van Wincoop, 2001, 2003, among others).

The estimated equation is:

$$\begin{aligned} \ln Xij = {} & \alpha_0 + \alpha_1 \cdot \ln Y_i + \alpha_2 \cdot \ln Y_j + \alpha_3 \cdot \ln P_i + \alpha_4 \cdot \ln P_j + \alpha_5 \cdot Adj_{ij} + \alpha_6 \cdot Isl_i + \alpha_7 \cdot Land_{ij} + \\ & + \alpha_8 \cdot CACM + \alpha_9 \cdot CARIC + \alpha_{10} \cdot MERC + \alpha_{11} \cdot NAFTA + \alpha_{12} \cdot CAN + \alpha_{13} \cdot UE + \alpha_{14} \cdot \ln Dist_{ij} \quad (3) \\ & + \alpha_{15} \cdot Lang_{ij} + \alpha_{16} \cdot TAI_i + \alpha_{17} \cdot TAI_j + \alpha_{18} \cdot Inf_i + \alpha_{19} \cdot Inf_j + u_{ij} \end{aligned}$$

where *ln* denotes natural logarithms.

The model is estimated with data for 62 countries in 1999 and a total of 3782 bilateral trade flows are obtained. 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 a value of 1 when countries share the same border and zero otherwise, Isl_i takes a value of 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 a value of 1 when countries are members of the agreement, CAN is a dummy representing Andean Nations Community members and UE takes a value of 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. Since suitable direct measures of distance costs are unavailable, geographical distance between countries is often used as a proxy in gravity equations, so $Dist_{ij}$ is the geographical great circle distance in kilometres between the capitals of country *i* and *j*. $Lang_{ij}$ is a dummy for countries sharing the same language, 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 criteria followed by the 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 classification obtained is slightly different to the *Human Development Report* classification for 2001 because we calculate the averages for OECD member country indicators and we use them to fill the gaps of missing data for some OECD countries, thus increasing the sample size. Our first results can be summarised in a ranking[4] that includes five additional countries if we compare it with the United Nations Development Programme's ranking, these nations being 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 in one group and the first in the next group (see UNDP, 2001 and Archibugi and Coco, 2002).

Infrastructure variables are calculated with the kilometres of paved roads and motorways per square kilometre, but penalising the former. We use equation (4) to calculate the index.

$$Infrastructure\ \text{var}iable = \frac{((0.75 \cdot paved\ \ roads(km)) + motorways(km))}{Land\ \ area(km^2)} \qquad (4)$$

In order to investigate the presence of multicolinearity, 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%. Additionally, equation (3) is estimated using White's transformation to obtain consistent standard errors in our regression, since White's Test indicates the presence of heteroscedasticity in the data.

Table A.2 in appendix A[5] shows a summary of the data used in our analysis.

Table 1 shows our results. 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

[4] Appendix A. Table A.1. The three columns show the TAI ranking, the list of countries classified and the TAI value.

[5] 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.

importer. It also takes into account the fact that higher income economies tend to be more interested in product differentiation and specialisation, 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 this depends on the specialisation of countries. Developed countries can be considered as manufacturing exporters and developing industrialising countries can been seen as non-manufacturing 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 has a negative sign, as expected, because lower distances imply lower transport costs and a higher amount of goods traded.

Model 2 shows the effect of geographical distance on bilateral trade. Distance only explains 11% of the variability of export flows. Therefore, other geographical variables are included in the gravity equation, namely adjacency, being an island and being landlocked. Moreover, we expect history, culture, language and social relations to also have important effects on trade. The adjacency coefficient is expected to be positive since countries sharing a border trade more, and the landlocked coefficient is expected to be negative, since countries without direct access to the sea trade less. History, culture and social relations will also have important effects on trade. Language is included as a proxy for this type of relationship between countries. Its coefficient is expected to be positive.

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; in fact 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 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 dummy: NAFTA. 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):

$$\begin{aligned}\ln Xij = {} & \alpha_0 + \alpha_1 \cdot \ln Y_i + \alpha_2 \cdot \ln Y_j + \alpha_3 \cdot \ln P_i + \alpha_4 \cdot \ln P_j + \alpha_5 \cdot Adj_{ij} + \alpha_6 \cdot Isl_i + \alpha_7 \cdot Land_{ij} + \\ & + \alpha_8 \cdot CACM + \alpha_9 \cdot CARIC + \alpha_{10} \cdot MERC + \alpha_{11} \cdot NAFTA + \alpha_{12} \cdot CAN + \alpha_{13} \cdot UE + \\ & + \alpha_{14} \cdot \ln Dist_{ij} + \alpha_{15} \cdot Lang_{ij} + \alpha_{16} \cdot ArCo_i + \alpha_{17} \cdot ArCo_j + \alpha_{18} \cdot Inf_i + \alpha_{19} \cdot Inf_j + u_{ij}\end{aligned} \tag{5}$$

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: UE. We find the same R^2 as 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 also attempt to analyse if technology has an effect on geographical distance. We use the method suggested by Freund and Weinhold (2004), creating a dummy variable, LONGDIST, which takes a value of 1 when distance between the exporter and the importer exceeds the average distance among all countries. Then, we interact TAI and LONGDIST, obtaining *LONGDISTi* ($LONGDIST*TAI_i$) and *LONGDISTj* ($LONGDIST*TAI_j$). If technology and the advance of the Information and Knowledge Age have reduced (increased) the impact of distance on trade, then the coefficient on the interaction term should be positive (negative). However, these coefficients are positive but non-significant.

As we compose *LONGDISTi* and *LONGDISTj* with TAI_i and TAI_j, we use ArCo instead of TAI in Model 11 to analyse the effect of the knowledge-based economies on trade. Since the coefficient of *LONGDISTi* and *LONGDISTj* are both positive and significant, our results offer evidence that the Information and Knowledge Age has altered the effect of distance on trade.

In order to understand whether there exists a differential behaviour concerning the determinants of trade flows for developed and developing countries, the 62-country sample is divided into several groups according to their level of economic development.

This classification is made up of three groups: countries with high GDP per capita, medium GDP per capita and low GDP per capita. Countries are ordered from higher to lower income levels, and then an upper level of GDP is composed by calculating the average of the first half of the sample, and an inferior level is set by calculating the average of the second half. In order to study the evolution and convergence of the groups, the annual average of the GDP per capita for countries in each group is calculated. The data do not show an *absolute* β*-convergence* or σ*-convergence* trend among the groups of countries considered over the period 1990-2002 (Figure 1, in Appendix B). As Sala-i-Martin (1996) points out, there is *absolute* β*-convergence* if poor economies tend to grow faster than richer ones and σ*-convergence* can be observed when there is a decrease in the dispersion of the real GDP per capita levels of economies over time.

Figure 1 (Appendix B) shows that the lack of *absolute* β*-convergence* (rich countries grow faster) is associated with the dispersion among the three groups, which has not fallen (there is no σ*-convergence*).

Sala-i-Martin (1996) focuses on *conditional* β*-convergence*, the prediction that poor economies should grow faster than rich ones holds true only if all economies converge to the same steady state. A way to hold the steady state of an economy constant is to restrict the convergence study to sets of countries for which the assumption of similar steady states is not unrealistic. Therefore, *conditional* β*-convergence* could be observed if more or less similar countries were compared in an international framework. One explanation of why an *absolute* β*-convergence* cannot be found is that dissimilar countries are included in the 62-country sample and thus the effect of other agents is prevailing.

Table 3 shows the main results of the augmented gravity model for the richest and the poorest countries in our sample. Only two groups are considered instead of three in order to have a higher contrast between them.

In Model 12 and 13, the individual effect of distance on trade is analysed for the richest and the poorest economies respectively. The geographical distance coefficient is significant and negative, as expected, although it only explains 4% of the variability of export flows for the richest countries and 7.4% for the poorest countries.

Model 14 presents the OLS results for the augmented gravity equation in the richest countries. Results show that importer's income, adjacency, island and landlocked dummies, geographical distance, exporter's T AI and exporter's transport infrastructure are significant. These variables have the expected sign. Demographic variables (population of the countries) are non-significant. As Filippini and Molini (2003) explain[6], "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 this model explain 87.7% of the variability in exports.

In Model 15 the augmented gravity model is estimated for the poorest countries. Exporter's and importer's population, being landlocked, geographical distance, the language dummy, and the exporter's and importer's TAI are significant and they have the expected sign. Demographic variables for exporters have a positive relation with trade, indicating that greater availability of cheap labour force for industries in developing countries fosters trade. Variables in this model explain lower variability in exports than the richer economies (66.8%).

[6] Filippini and Molini, 2003, page 701.

In relation to income coefficients, our results do not show evidence that the costs and benefits of integration and globalisation are unevenly distributed among the richest and the poorest countries, since income coefficients are not significant for the poorest economies.

Technological and transport infrastructure variables are expected to be positive, yet they are non-significant for importers when trade is among the richest countries, and only technological variables are significant for the poorest countries. One explanation could be the non-arrival at a minimum level of transport infrastructure in developing countries. Technology and transport infrastructure can be considered as barriers to trade for those countries with lower endowment levels; thus, investing in these variables could foster international trade and increase the participation of the poorest economies in a more globalised and integrated world.

Finally, following Dollar and Kraay (2004) two kinds of developing countries could be considered: globalisers and non-globalisers. These authors point out that members of the globaliser developing group show an increase in their growth rates over the decades 1970s-1990s. The authors support the view that open trade regimes lead to faster growth and poverty reduction in poor countries. In this line, Ades and Glaeser (1999) argue that growth may be a function of the size of the market, and therefore globalisation, integration and openness foster development in the poorest countries. Moreover, Coe *et al.* (1997) support the importance of trade as a vehicle for technological *spillovers* and that a greater degree of openness fosters an increased stock of knowledge in developing countries.

According to Dollar and Kraay (2004), the poorest countries considered in this paper are classified as being either globalisers or non-globalisers[7]. The methodology employed previously for dividing groups with different levels of development is used again, but only positive rates of growth in trade are taken into account to calculate the upper (63.12%) and the lower limits (15.31%). Some countries with low income levels (Syrian Arab Republic, El Salvador, China, Honduras, Nicaragua, India, Ghana, Senegal, Nepal and Mozambique) could be included in a globaliser developing group because they have a high-medium rise in participation on trade.

5. Conclusion

In this paper we estimate a gravity equation augmented with technological and transport infrastructure variables in order to analyse the impact of these variables 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.

A great number of authors have shown that economic geography determines trade flows. Others have studied the importance of infrastructure endowments in countries and transport costs on 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 the variables included have expected sign and are significant, excluding some integration variables. We show that distance have a considerably low explanatory power on trade compared with transport infrastructure and technology.

[7] Dollar and Kraay (2004) use two different measures to identify post-1980 globalisers, namely the growth in trade relative to GDP and the reduction in average tariff rates. They argue that both measures have their strengths and weaknesses. Trade volumes reflect other factors other than trade policy and the average tariff rate does not reflect non-tariff barriers to trade.

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 transport infrastructure and technology leads to the improvement and maintenance of the level of competitiveness. These variables can be considered as a barrier to trade for countries with lower endowment levels and therefore investing in them increases the participation of the poorest countries in the world economy.

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

Finally, in order to infer whether there is a differential behaviour among countries we divided our sample into three groups according to their level of development. 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. Maybe a globaliser and non-globaliser world should be considered since the growth rates of the former are accelerating while the poorer non-globaliser countries are falling further and further behind.

In our sample, geographical factors are always relevant, but technological and social factors seem to be more important for the poorest economies than for the richest ones. A matter of further research could be to study in further depth these aspects with regard to developing countries. Finally, a panel data estimation for a longer period would be desirable since the performance of trading blocs and the evolution of the importance of geography and technology could be analysed in an environment marked by globalisation and technological change.

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Table 1. Determinants of international trade. Baseline model and contribution of specific variables.

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
Constant term	-10.42*** (-11.94)	21.29*** (44.33)	3.69*** (22.45)	8.95*** (107.64)	4.07*** (23.19)
Exporter's income	0.27*** (13.22)	-	-	-	-
Importer's income	0.22*** (11.47)	-	-	-	-
Exporter's population	0.70*** (23.08)	-	-	-	-
Importer's population	0.51*** (15.79)	-	-	-	-
Adjacency dummy	-	-	-	-	-
Island dummy	-	-	-	-	-
Landlocked dummy	-	-	-	-	-
CACM dummy	-	-	-	-	-
CARICOM dummy	-	-	-	-	-
MERCOSUR dummy	-	-	-	-	-
NAFTA dummy	-	-	-	-	-
CAN dummy	-	-	-	-	-
UE dummy	-	-	-	-	-
Distance	-1.38*** (-31.19)	-1.25*** (-22.07)	-	-	-
Language dummy	-	-	-	-	-
Exporter's TAI	-	-	9.53*** (38.97)	-	-
Importer's TAI	-	-	7.21*** (29.01)	-	-
Exporter's ArCo	-	-	-	-	7.83*** (32.67)
Importer's ArCo	-	-	-	-	5.91*** (24.29)
Exporter's infrastructure	-	-	-	1.5*** (21.23)	-
Importer's infrastructure	-	-	-	1.23*** (15.92)	-
R-squared	0.407	0.113	0.401	0.187	0.323
Adjusted R-squared	0.406	0.113	0.4	0.187	0.322
S.E. of regression	2.511	3.069	2.524	2.939	2.683
Number of observations	3126	3126	3126	3126	3126

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$). Income, population and distance are also in natural logarithms. The estimation uses White's heteroscedasticity-consistent standard errors.

Table 2. Determinants of international trade. Augmented gravity model.

Variable	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11
Constant term	-15.38*** (-25.71)	-15.42*** (-25.81)	-19.24*** (-31)	-19.31*** (-31.44)	-14.37*** (-21.18)	-17.01*** (-24.41)
Exporter's income	0.02*** (2.62)	0.02*** (2.64)	0.05*** (6.35)	0.05*** (6.33)	0.02** (2.34)	0.04*** (5.61)
Importer's income	0.04*** (3.72)	0.04*** (3.73)	0.06*** (5.21)	0.06*** (5.19)	0.04*** (3.51)	0.05*** (4.65)
Exporter's population	0.89*** (49.34)	0.89*** (49.41)	0.97*** (53.45)	0.97*** (53.47)	0.89*** (49.5)	0.98*** (53.6)
Importer's population	0.66*** (34.92)	0.66*** (35)	0.71*** (36.5)	0.71*** (36.44)	0.67*** (34.66)	0.72*** (36.43)
Adjacency dummy	0.43*** (2.89)	0.46*** (3.1)	0.38** (2.34)	0.38** (2.32)	0.31** (2.03)	0.13 (0.8)
Island dummy	-0.46*** (-5.64)	-0.46*** (-5.64)	-0.27*** (-3.17)	-0.26*** (-3.15)	-0.46*** (-5.58)	-0.28*** (-3.26)
Landlocked dummy	-0.86*** (-11.34)	-0.86*** (-11.35)	-1.04*** (-13.82)	-1.04*** (-13.83)	-0.86*** (-11.29)	-1.02*** (-13.68)
CACM dummy	1.95*** (8.08)	1.94*** (7.99)	2.41*** (9.27)	2.43*** (9.46)	1.74*** (6.96)	1.95*** (7.22)
CARICOM dummy	4.29*** (4.49)	4.29*** (4.49)	4.07*** (4.03)	4.08*** (4.05)	4.24*** (4.44)	3.99*** (3.95)
MERCOSUR dummy	2.58*** (7.66)	2.55*** (7.57)	2.91*** (8.72)	2.92*** (8.82)	2.56*** (7.18)	2.85*** (7.62)
NAFTA dummy	0.71 (1.16)	-	1.12* (1.65)	1.14* (1.7)	0.81 (1.31)	1.31* (1.85)
CAN dummy	1.22*** (2.61)	1.19** (2.55)	1.06** (2.22)	1.07** (2.24)	1.26*** (2.69)	1.14** (2.4)
UE dummy	-0.24** (-2.54)	-0.25** (-2.61)	-0.11 (-1.1)	-	-0.22** (-2.36)	-0.09 (-0.89)
Distance	-1*** (-26.72)	-1*** (-26.73)	-0.95*** (-24.82)	-0.93*** (-26.79)	-1.12*** (-20.55)	-1.2*** (-21.8)
Language dummy	0.92*** (11)	0.92*** (11.03)	0.91*** (10.41)	0.91*** (10.46)	0.93*** (11.16)	0.93*** (10.78)
Exporter's TAI	9.12*** (46.46)	9.13*** (46.6)	-	-	9.01*** (42.97)	-
Importer's TAI	6.39*** (30.7)	6.4*** (30.79)	-	-	6.2*** (27.19)	-
Exporter's ArCo	-	-	7.71*** (46.75)	7.69*** (47.12)	-	7.48*** (43.72)
Importer's ArCo	-	-	5.44*** (30.08)	5.43*** (30.23)	-	5.21*** (26.8)
Exporter's infrastructure	0.68*** (17.65)	0.68*** (17.6)	0.91*** (25.06)	0.91*** (25.11)	0.67*** (17.34)	0.88*** (23.63)
Importer's infrastructure	0.57*** (12.57)	0.56*** (12.52)	0.74*** (17.45)	0.74*** (17.41)	0.56*** (12.31)	0.71*** (16.51)
LONGDISTi	-	-	-	-	0.21 (0.99)	0.59*** (2.75)
LONGDISTj	-	-	-	-	0.36 (1.53)	0.59** (2.52)
R-squared	0.788	0.787	0.781	0.781	0.788	0.783
Adjusted R-squared	0.786	0.786	0.779	0.779	0.786	0.782
S.E. of regression	1.506	1.506	1.529	1.529	1.505	1.522
Number of observations	3126	3126	3126	3126	3126	3126

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$). Income, population and distance are also in natural logarithms. The estimation uses White's heteroscedasticity-consistent standard errors.

Table 3. Determinants of international trade. Estimation results for high and low income countries.

Variable	Model 12	Model 13	Model 14	Model 15
Constant term	16.92*** (17.94)	14.92*** (11.06)	-31.11*** (-3.21)	-12.83*** (-4.73)
Exporter's income	-	-	1.03 (1.53)	-0.04 (-0.56)
Importer's income	-	-	1.29* (1.93)	-0.05 (-1.28)
Exporter's population	-	-	-0.23 (-0.32)	1.25*** (10.86)
Importer's population	-	-	-0.48 (-0.7)	0.57*** (6.05)
Adjacency dummy	-	-	0.47** (2.5)	0.36 (0.73)
Island dummy	-	-	0.27* (1.92)	3.32 (0.9)
Landlocked dummy	-	-	-0.37*** (-2.84)	-1.12*** (-2.76)
Distance	-0.37*** (-3.14)	-0.83*** (-5.09)	-0.93*** (-12.09)	-1.36*** (-7.24)
Language dummy	-	-	-0.07 (-0.43)	1.23*** (2.89)
Exporter's TAI	-	-	2.41*** (2.81)	5.51** (2.48)
Importer's TAI	-	-	1.08 (1.17)	6.46*** (3.09)
Exporter's infrastructure	-	-	0.22*** (3.07)	-2.86 (-0.72)
Importer's infrastructure	-	-	-0.01 (-0.17)	0.18 (0.3)
R-squared	0.045	0.079	0.886	0.694
Adjusted R-squared	0.039	0.074	0.877	0.668
S.E. of regression	2.01	2.89	0.719	1.728
Number of observations	182	165	182	165

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$). Income, population and distance are also in natural logarithms. The estimation uses White's heterosc edasticity-consistent standard errors.

APPENDIX A

Table A.1.The technology achievement index.

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 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 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
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:

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

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

Dynamic Adopters (from 0.19 to 0.34). Countries in this group try to achieve growth in their technology content and in their level of development.

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 to low income levels. The relative position is not particularly meaningful due to the lack of adequate data.

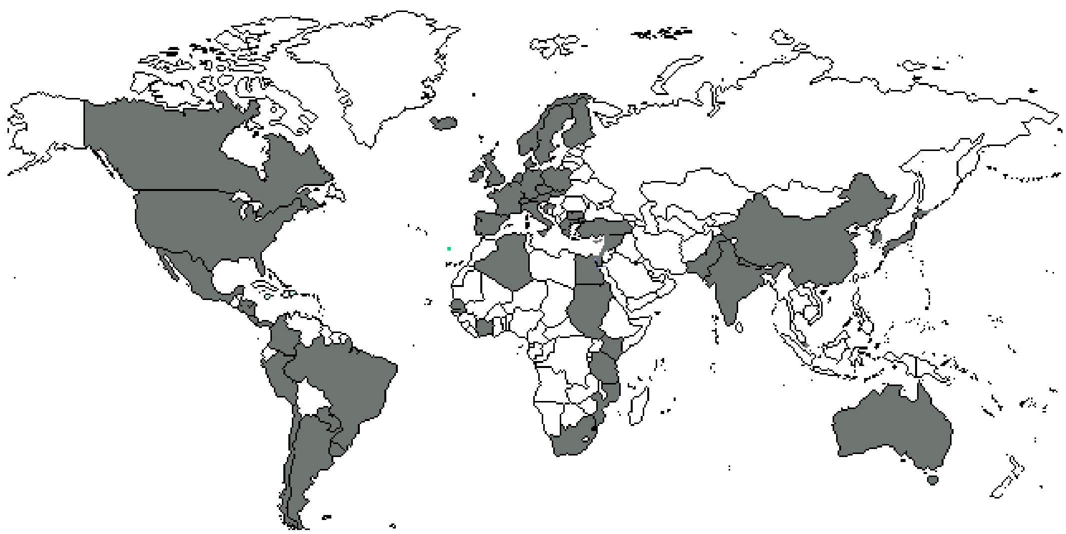
Table A.2: Variable descriptions and sources of data.

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

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

APPENDIX B

Figure 1: Countries utilised in the analysis.



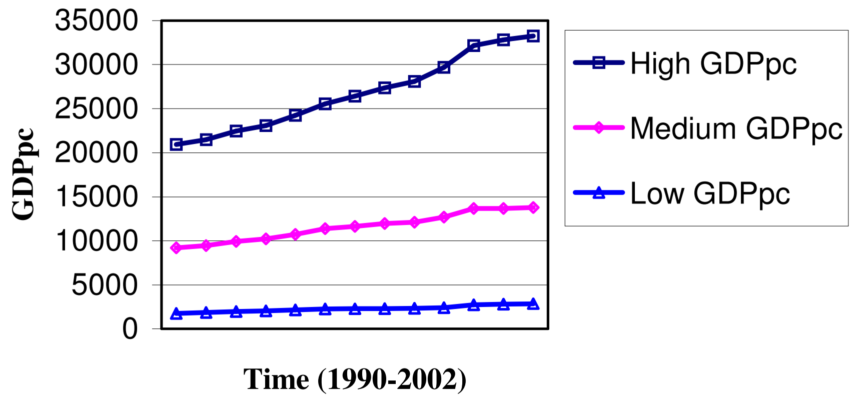
Leaders: Finland, United States, Sweden, Japan, Rep. of Korea, Belgium-Luxembourg, Netherlands, United Kingdom, Singapore, Switzerland, Canada, Australia, Germany, Norway, Ireland, Denmark, Austria, Iceland, France, Israel.

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.

Marginalised: Nicaragua, Pakistan, Senegal, Ghana, Kenya, Nepal, Tanzania, Sudan, Mozambique.

Figure 2: Groups of countries.



Countries with high GDP[8]: 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.

[8] GDP per capita, PPP (current intern $). Source: World Development Indicators (2003).