On the Determinants of the International Embodied Technology Diffusion

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Abstract

This paper addresses the question of why some countries adopt more embodied technologies in the long-term than others. Using a cross section of countries and examining imports of capital goods originated in OECD countries for the period 1965 to 1995, results indicate that trade openness was robustly correlated with technology adoption, suggesting that manufacturing imports are a principle channel for international knowledge spillovers. Another finding suggest that physical and human capital investment allow countries to import more technologies per worker from OECD countries. Furthermore no skill-biased technological transfer has been detected from OECD economies to the rest of the world in such period of time. Intellectual property rights protection index and trade policy play an important role while other control variables such as agricultural share and manufacturing share do not play a significant role.

Keywords: Technology diffusion, catching up, institutions, skills, developing countries, openness.

Introduction

Recent theoretical growth models help to explain why and how world technology frontier advances spur overall standards of living. However, most of this theories do not explain the movement of countries that operate below the world technology frontier. The catch-up process is the most forgotten topic in a decade of intense empirical research on technology and growth. The majority of the world adopts technologies developed by other countries. In fact, according to several indicators, such as R&D investments or number of patents, innovation is highly concentrated in a few countries. Abramovitz (1986) depicted the process of catching-up as the social capability of a country to absorb more advanced technologies. Several constraints define its realization, such as facilities for the diffusion of knowledge, mobility of resources among sectors, and capital accumulation. Based on these ideas, this research addresses the empirical question of why some countries tend to adopt more technologies in the long-run.

Technology is embodied in physical goods, especially in R&D investment intensive goods. When a firm replaces an old capital good with a new capital good, it is not just investing resources in capital and increasing the stock of aggregate fixed capital; it means, as well, introducing a better-quality technology in the production process, increasing the total factor productivity. De Long and Summers (1991) provide empirical evidence of the strong effects of equipment investment on growth in developed and developing countries. Greenwood *et al*. (1997) attribute 60 percent of US long-term growth to embodied technological change. The long-term productivity of a country that operates below the world technology frontier depends on the adoption of new vintages of machineries and on the ability to use them. The production of capital goods is, as in the case of R&D investments, highly concentrated in just a few countries, and therefore, the rest of the world's economies are foreign technology adopters. The international trade of sophisticated goods is a channel that facilitates diffusion of technologies and knowledge throughout the world. Lee (1995) found a positive relationship between the rate of machinery imports from OECD countries and per capita growth in 89 countries. Results of Coe and Helpman (1995) and Coe *et al.* (1997) indicate that international technological spillovers are related to machinery and equipment imports. If capital and intermediate goods are a source of long-term productivity improvement, it seems reasonable to ask why some countries adopt more technological engines from leading economies than do others. Measuring the amount of knowledge intensive goods that flow from technologically advanced economies to the rest, we can obtain a measure of the overall effort a country exerts in the adoption of new embodied technologies.

This paper estimates the determinants of foreign technology adoption effort in a cross section of countries between 1965 and 1995, using a panel data technique. The main result was that openness to international trade and education of labor force play a key role in the adoption of new technologies. The paper is organized as follows. The first section examines the world map of technology and identifies producers and potential adopters. The second section analyzes the determinants of technology adoption. The third section discusses the results. Finally, section four summarizes the main conclusions of this research.

A Look at the Data on Technology

A preliminary question faced in this study was how to measure technology adoption. *Technology* is defined as the quality of capital and intermediate goods used in the production process at any given time. This is, of course, a narrow definition of technology, and does not take into account the disembodied technologies. However, trying to measure a broader definition of technology is very difficult, and ascertaining the amount of international disembodied technology flows more difficult still. The technology adoption process is an investment resources process for updating and upgrading the quality of the capital installed. The capital is a heterogeneous composite of different kinds of goods, such as machinery and instruments. To our knowledge there is no international data on disaggregate production or investment for a large number of countries and periods and no index allowing the comparison of capital's quality. Furthermore, one advantage of this definition of technology is that although the production of capital goods is highly concentrated in a few countries, as Eaton and Kortum (2001) have shown, the imports of capital and intermediate goods emerge as a reasonable proxy for technology adoption investments.

Technology Production and the Quality of Capital

In the absence of detailed international production data on capital and intermediate goods, the analysis has been focused on the trade flows of machinery, instruments and fine chemical products because those sectors are R&D intensive in the developed world[1]. The theory suggests that a country with comparative advantage in the production of knowledge intensive goods must show a significant presence of such products in the trade pattern. Balassa (1965) designed an index to measure the comparative advantage of a product or group of products based on its appearance in the export pattern. The revealed comparative advantage index (RCA) in a product *i* and a country *j* is described by the expression

(1) $$RCA_{ij} = \frac{X_{ij} / \sum_j X_{ij}}{\sum_i X_{ij} / \sum_i \sum_j X_{ij}}$$

where X_{ij} is machinery, instruments and fine chemicals exports (in US current dollars) in country *j* at a given moment in time. A value of 1.2 shows that country *j*'s technology exports relative to its total exports are 20 percent higher than the share of world technology exports relative to total world exports. Hence, an RCA index of less than one for a country can be interpreted as a technological disadvantage.

Figure 1 shows the world's technological change experienced since 1965 and revealed in the export pattern among OECD countries and the rest of the world. In 1965, the technology gap was tremendous, but has diminished significantly in the last thirty years. During this period, the ability to export technology to world markets has been concentrated in OECD countries as a sign of technological superiority, and especially in a small group of OECD countries shown in Table A2 in the Appendix. The advance experienced by developing economies is, as well, concentrated in a handful of economies located in East Asia and Latin America.

INSERT FIGURE 1

These kinds of goods are by definition R&D intensive investments in developed countries. Figure 2 shows a strongly positive relationship RCA in technological products and R&D expenditures. The more a country invests in R&D, the greater relative technological advantage it has in the export pattern. Countries as Thailand, Mexico and Singapore behave as outliers, since none of these economies would be expected to reveal a technological advantage in the RCA index, due to their low level of R&D expenditure.

However, they still have an RCA index greater than one due to the fact that they are importers and assemblers of technological components.

While technological advantage and R&D effort may or may not be positively related in a cross-section of countries, the quality of the capital and intermediate goods is certainly related to the level of new embodied knowledge. Unfortunately, the ability to control for this feature is not possible within the existing classifications of international trade. Instead, Figure 2 supports the view that goods quality can be approximated based on the origin of the goods. A machine produced in an OECD country is more likely to be of better quality than one produced in the Philippines, because OECD countries allocate more relative R&D resources to produce new machines than the rest of the world economies. Hence, a country's R&D expenditure could be a criteria for measuring the quality of a machine.

Technology Imports as Technology Adoption

Exports of technological goods give a first picture of the world's technology map. On one hand, developed economies account for the largest world capital and intermediate goods production, and relative R&D expenditures. As a consequence, developed countries reveal in the export pattern a technological advantage in technological products. On the other hand, there are technology adopter economies. Identifying an ideal indicator of effort in technology adoption is not easy because there is no way to measure internationally the investment in sophisticated new capital goods over a long time span. Hence, imports of capital and intermediate goods have been used as a proxy of this variable. The accuracy of the adoption indicator will be greater in countries without a technological domestic sector. In economies able to produce capital goods, the index of imports will be a less suitable one of technology adoption effort. For that reason, the total sample was divided into different sub-samples, attending to the ability to produce domestic substitutes for technological goods. The total sample includes all the countries with technology importation data, the Non-OECD sample excludes from the total sample the OECD economies, and the Non-Technological Advantaged sample excludes from the total sample those countries with a technological disadvantage, as revealed in the export pattern.

In Table 1, country group averages measuring the total effort in acquisition of technological products were recorded. All the variables are expressed in per worker terms, dividing each import category according to the World Bank (2001) labor force measure.

INSERT TABLE 1

It is worth noting the low amount of total technology imports relative to total manufacturing imports in each group. The comparison among groups reveals several important facts. OECD countries tend to import more technologies than any other group per worker, as expected. Furthermore, each group tends to import a higher amount of capital and intermediate goods from Non-OECD countries. This fact is mainly explained in terms of location of unskilled intensive assembling processes in developing countries and the slicing up of the value chain implemented. Additionally, non-technologically advantaged countries tend to invest more in capital and intermediate goods from OECD countries than the Non-OECD group. This fact supports the idea of the non-substitutability of the OECD capital goods in terms of domestic production. In other words, knowledge intensive products are differentiated by their origin because OECD capital goods are more R&D –and knowledge– intensive than Non-OECD goods.

The Determinants of Technology Adoption

The index of technology adoption is the technology imports per worker from OECD countries. The question is, what macroeconomic and institutional variables determine investments in new technologies in the long term? Different specifications in different samples of the equation were estimated

$$\text{(2)} \qquad \log(M^{jt}) = \alpha + X^{jt}\beta + u^{j} + v^{t} + \varepsilon^{jt}$$

where M^{jt} is per worker capital and intermediate goods imports from OECD countries, measured in current US dollars in country *j* and time *t*. X^{jt} is a macroeconomic and institutional set of explanatory variables trying to approach the social capability to absorb advanced technologies, u^{j} is a fixed country effect, v^{t} is a set of time dummies, and ε^{jt} is an error term identically and independently distributed across countries and time. Several *X* variables, such as education and the intellectual property rights protection index are not available at annual frequency. Therefore, a panel with a cross-section of a maximum of 69 countries, from 1965 to 1995, at five year intervals was used.

Although in cross-country regressions there is controversy over the most suitable econometric technique to deal with the fixed country effect u^{j}, it is well argued, as in Caselli and Coleman (2001), that by introducing regional dummies and estimating random effects, it is possible to balance the trade-off between consistency and efficiency among the random effects (RE) and the fixed effects (FE) estimations[2].

The case of reverse causation is unlikely to be a problem because of the small magnitude of technology imports. Hence, it is unlikely to have induced changes in the macroeconomic and institutional variables considered. However the possibility of bias derived from the omission of important variables cannot be ruled out.

This study is carried out using different samples. First, the total sample including OECD and Non-OECD countries. Then, smaller samples such as, the Non-OECD and the group comprised of technologically disadvantaged countries.

Total sample

Table 2 summarizes the basic results derived from the total sample estimation. Each column represents a different specification of the model. The first one includes the main set of predictors, the second one shows the role of different level of education variables, and the others are extensions from the first one trying to decompose the influences of trade openness in technology adoption. The following set of variables were considered as the explanatory set in X: log of investment per worker, an index of intellectual property rights protection ranked from less (0) to more (5) protective patent legal systems as calculated from Ginarte and Park (1997), a dummy for landlocked countries, the Sachs and Warner (1995) trade policy openness index adopting a cero value for closed economies and a one value for open economies, agriculture and manufacturing shares, a dummy for land locked economies, the log of the fraction of the population over 15 years old with completed primary education, and the rate of trade openness as measured by the log of total exports and imports per worker.

Each of the equations was estimated including a year and a continental dummy, as explained in Table A2. Those coefficients have been omitted due to space restrictions.

In column 1, six variables have a significant effect[3] on technology adoption. Openness to exports and imports is the highest coefficient, followed by landlocked dummy, investment per worker, Sachs and Warner openness index, intellectual property rights index and education attainment of labor force. All the variables have the expected sign with the exception of trade policy index, which is discussed below.

In column 2, human capital potentially relevant to technological adoption was divided into three different levels: percentage of the labor force with any primary education, percentage of the labor force with any secondary education and percentage of the labor force with any tertiary education. The effect of the educational levels on technology adoption is positive, although higher levels of education have a decreasing impact on technology adoption. However, only the primary education coefficient is statistically significant. The rest of the variables maintain the same sign and significance.

INSERT TABLE 2

Column 3 reports the estimates of the model once openness to trade per worker are divided into exports and imports. The import's coefficient is larger than the export's coefficient, but only the first one is significant.

Column 4 extends the role of openness in technology adoption to exports. Exports are broken down into manufacturing and non-manufacturing exports and the only significant coefficient is the one of manufacturing exports variable. The rest of the coefficients do not show important changes, except the intellectual property rights protection index that it is now only significant at the 10 per cent level. In Column 5 imports per worker were split off into manufacturing and non-manufacturing imports. The non-manufacturing import per worker variable is non significant but the other is significant at the maximum level and exerts a large influence on technology adoption. Once trade openness is decomposed in column 5, the investment per worker and the property right index become non-significant. If exports are dropped from the equation, both manufacturing and non-manufacturing imports are highly significant.

Finally, goodness of the fit is very high for all model specifications.

Non-OECD sample

Figure 1 shows that OECD countries as a group reveal a technological advantage in their export pattern. Technology flows from developed to developing countries trough trade, becoming Non-OECD countries the most important group of potential adopters. In Table 3 the same strategy estimation followed for the total sample has been used.

The results are quite similar to those reported in the total sample. However, several differences emerged. First of all, the SW index is not significant[4] in columns 1, 2 and 3. Manufacturing exports are positive and significant when imports are not divided into manufacturing and non-manufacturing. The negative effect of lack of access to an ocean on technology adoption is even stronger in developing countries. The education variables are not significant in the first column, however, estimating the same equation using the portion of the adult population with non-completed but with some primary studies, those coefficients become highly significant.

INSERT TABLE 3

Technologically disadvantaged sample

The former sub-sample may be more accurate than the latter one in measuring and identifying the determinants of technology adoption. The Non-OECD sample is a very heterogeneous group because it excludes OECD economies with non-domestic capital goods sector, and includes new industrializing economies with the ability to produce and export machinery, equipment and other sophisticated goods. In the technologically disadvantaged sample, only countries with no domestic technological sector were considered. Hence, to avoid underestimating the adoption phenomena, those countries that in 1995 revealed in their export pattern a technological RCA index larger than 1 were excluded from the total sample.

INSERT TABLE 4

The main results are reported in Table 4. The magnitude and significance of the levels of the coefficients estimated are very similar to those reported in the Non-OECD sub-sample. However, some differences should be noted. First, the Sachs and Warner trade policy index has a significant[5] and negative influence on technology adoption in the last three columns. Second, geographic isolation remains as a powerful predictor but less strong than in the former sample. And the effect of primary completed education is clearest than in the Non-OECD sample.

Discussion

Why do some countries tend to invest more per worker in the long run in adopting new technologies embodied in goods? According with the theoretical literature a broad set of variables have been tested as potential explanations. Openness to international trade is one of the most relevant and robust determinants of technology adoption. But economies have to make a domestic effort to adopt new technologies investing in physical and human capital. Geographical features of the countries can affect the technology adoption, economies with no ocean access import less technology per worker than others. Trade policy and high quality institutions as measured by the Sachs and Warner openness index and the degree of protection of the intellectual property rights are less robust determinants. The rest of the variables studied played a minor role in technology adoption.

A robust link exists between several openness measures and technology adoption. In the three samples, trade openness has the highest coefficient and is estimated with great precision. A 10 percent increase in exports and imports per worker generates a 6.5 percent increase in technology adoption in the total sample, a 5.8 in the Non-OECD sample and more than 6.1 per cent in the Technologically Disadvantaged sample. Disaggregating trade between exports and imports results show that imports were the only channel of influence of trade openness in technology adoption. To test the robustness of this finding exports were divided into manufacturing and non-manufacturing products, and the result shows that a 10 percent increase in manufacturing exports leads to a roughly 0.5 percent increase in technology adoption. Most important determinant of adoption are imports, especially manufacturing imports. A 10 percent increase in manufacturing imports per worker promoted a seven percent rise in investment in OECD technologies per worker in the three samples. It is worth noting that technology imports are only a small fraction of manufacturing imports, as showed in Table 1. Hence it is not likely that growth in imports was driven by technology imports.

These findings can be interpreted as evidence of international knowledge spillovers linked to trade. There is a great deal of new theoretical[6] and empirical[7] literature stressing the role of international trade as a channel for knowledge and technology diffusion around the world. Trade allows the flow of ideas beyond national borders and the learning from others' experience in the acquisition and use of new technologies. So, when economies are open to trade, especially to imports of manufacturing products, they are not simply buying products from abroad; they are establishing information channels that are extremely useful for the transfer of free knowledge. The kind of knowledge that flows from other countries is likely to result from experience rather than from R&D investments, so it is a complement to the knowledge embodied in capital and intermediate goods traded. The interaction between embodied and disembodied knowledge has to be carefully considered because it could be the origin of innovative processes in early stages of development. Technological progress is a complex phenomena depicted by Nelson and Winter (1982) as an evolutionary process of continued learning from others and innovation. This is possible because the domestic and the foreign knowledge are more complementary when differences in development are larger.

Openness to trade affects technology adoption from the export side as well, but to a much lesser extent than imports side. A 10 percent increase in manufacturing exports per worker leads to a rise in technology investment per worker of 0.5 percent in all the samples. This could confirm the spillover transmission channel, however, this finding has to be taken with care due to the significance level.

Another robust result pertains to the role of the educational level of the labor force in technology adoption. In the three samples, the attainment rate of primary education is positive and significant. A one-percent-point increase of the percentage of the population over 15 years old with complete primary studies resulted in a 1.9 percent rise in investment per worker in new technologies in the total sample, and a 2.3 percent rise in the technologically disadvantaged sample. That variable is not significantly different from zero in the Non-OECD sample, however, I have re-run the regression using the portion of adult population with some primary studies resulting a positive and significant coefficient. The analysis of the effects of educational levels confirms the less intuitive hypothesis of the importance of primary education in the adoption of new technologies. But no evidence has been found supporting the relevance of higher educational levels[8]. The robust link between primary education and technology adoption cannot confirm the idea of international skill-biased technological progress evidenced by Berman and Machin (2000). Instead, using a broader measure of technology, the evidence presented in this paper suggests that countries tend to adopt non-skill-biased embodied technologies. If adoption implies the use of new technologies, it appears that basic and elementary knowledge in the labor force are necessary for the acquisition of technological skills through learning-by-doing and learning-on-the-job new techniques.

Countries making an effort to invest in physical capital invest more in adoption of new technologies from abroad too. A 10 percent increase in domestic investment per worker leads to a 1.8 percent rise in technology adoption in the total sample, 2.1 in the Non-OECD sample and 2.2 in the Technologically Disadvantaged sample. This is of course an expected result, technological progress is an specific-investment process when technologies are embodied in capital goods.

Landlocked countries tend to trade less than others and hence invest less per worker in new OECD technologies. Geography imposes natural barriers on technology adoption by increasing transportation costs and reducing the knowledge spillover effect. This relationship is one of the most robust result across samples and specifications. An important feature of this coefficient is that it takes a higher absolute value in developing countries. Perhaps this is due to the effect of natural barriers in these economies with weaker transportation infrastructure.

Other important determinant of technology adoption is the protection of intellectual property rights. In a scale from 0 to 5 an increase in the protection degree of 0.5 points leads up to a 13.5 percent increase in technology adoption in the total sample, 13 per cent in the Non-OECD sample and 14 per cent in the Technologically Disadvantaged sample. North (1981) and Romer (1990) establish a link between intellectual property rights and technological progress[9]. The choice to transfer a technology to a developing country with a license over a patent could be discouraged if the intellectual property rights system do not allow to the technology owner of exclude others from using it or imitation.

One of the most controversial issues in growth empirics is the role of trade policy as measured by the SW openness index[10]. In these findings there is a robust and negative link between trade policy openness and technology adoption in the three samples. This negative effect was not expected and can be attributed to one of two factors: either the index is mismeasuring trade policy, as Rodriguez and Rodrik (1999) suggest, or trade policy is affecting imports other than technological ones. To avoid such a result, the tariff rate was included in the regressions, but results were not significant.

The rest of the variables displayed a less robust behavior either across samples or across specifications. The size of the manufacturing sector is a good predictor of technology adoption in one specification. A one percentage-point increase in the manufacturing share raised technology adoption by roughly one per cent in both the Non-OECD and technologically disadvantaged samples.

Conclusions

In this paper some macro-determinants of technology adoption in a cross-section of countries between 1965 and 1995 has been explained. Technology adoption has been measured in terms of imports per worker of goods with a high potential for technology diffusion. The potentiality has been quoted selecting the most R&D intensive goods produced and exported by OECD countries. The catch-up literature suggest that the ability to absorb more advanced technologies from abroad depend on specific social capabilities. The principle robust results suggest that openness to international trade, especially to imports, has an important explanatory power of technology adoption. The minor proportion of technology imports on manufactures imports excludes the possibility of reverse causation, so the causality seems to be that countries open to imports of manufacturing develop communication channels for absorbing free international knowledge stimulating technology adoption. This evidence support the view that technological progress diffuse not only with the trade of more and better goods but with the diffusion of free ideas existing in other countries. Institutional aspects as the protection of intellectual property rights play a key role in embodied technology adoption. However, remain in a puzzle whether stronger institutions are exogenous variables or are determined by the level of technology production. Political barriers to trade as measured by the SW index play an ambiguous role and a more robust finding is attributed to natural barriers, such an ocean access. The social capability to catch-up depends on the effort to invest resources in physical and human capital, as well.

Countries with higher investment per worker rates tend to adopt more advanced technologies. Primary education of the labor force is another robust determinant of technology adoption, but no robust link has been found to secondary or higher education. These main findings have political implications of great relevance and are open to discussion.

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Appendix 1: Statistical sources

R&D expenditure: UNESCO (1999).

Labor force: World Bank (2001).

Investment per worker: World Bank (2001)

Exports and imports: World Bank (1998).

Agriculture share: World Bank (2001).

Manufacturing share: World Bank (2001).

Intellectual Property Rights Protection Index: Ginarte and Park (1997) updated and provided by Walter Park.

Education attainment: Robert Barro y John Wha-Lee (2000).

Sachs and Warner openness index: Sachs and Warner (1995).

Landlocked: Easterly and Sewadeh (2001).

Technological goods: COMTRADE database.

Table A1: Technological goods

SITC Code rev.1	Technical progress diffuser goods
541, 553	Medicinal, pharmaceutical products and several cosmetics and toilet preparations (excluding soaps)
7111, 7112, 7113, 7114, 7115, 7116, 7117, 7118	Several machinery and equipment (excluding internal combustion engines)
722, 7231, 7249, 726, 729, 734	Specialized machinery for several industries (excluding machinery for manufacturing paper and food processing)
861, 862, 864	Machinery and instruments specialized for particular industries
9510	Other goods

Source: Standard International Trade Classification (SITC), revision 1and ECLAC (1996).

Appendix 2: Country data

Table A2: Technology country data, 1965-1995

			Technology imports from OECD countries per worker							RCA in technology	
Code	Country	Region	1965	1970	1975	1980	1985	1990	1995	1965	1995
AFG	Afghanistan	SA	1	1	3						
DZA	Algeria	MENA		29	85	184	116	99	125		0.01
AGO	Angola	SSA					13				
ARG	Argentina	LAC	12	23	65	102	56	71	173	0.06	0.23
AUS	Australia	OECD	60	77	120	243	229	362	523	0.17	0.29
AUT	Austria	OECD	51	102	249	616	538	1254	1689	0.69	0.84
BHS	Bahamas, The	LAC			456	776	1078				
BHR	Bahrain	MENA				836	779	1098	939		
BGD	Bangladesh	SA				3	4	3	3		0.06
BRB	Barbados	LAC		72	128	317	338	445	503		
BEL	Belgium	OECD	117	221	642	1488	1402	3209	4724	0.71	0.58
BLZ	Belize	LAC			227	161	144	238	212		
BEN	Benin	SSA	2	3		8				0.04	0.01
BOL	Bolivia	LAC	6	9	22	24	22	14	30	0	
BRA	Brazil	LAC	5	12	40	60	26	40	88	0.08	0.52
BRN	Brunei	EAP			296	378	212	229			
BFA	Burkina Faso	SSA	1	1	4	8				0.01	
BDI	Burundi	SSA	1		2						
KHM	Cambodia	EAP	3	2							
CMR	Cameroon	SSA	4	7	23	50		47	27	0.08	0.03
CAN	Canada	OECD	63	91	166	282	343	529	835	0.53	0.63
CAF	Central African Republic	SSA								0	0.03
TCD	Chad	SSA	1	2	8				4	0.02	
CHL	Chile	LAC	25	32	44	97	74	117	200	0.02	0.04
CHN	China	EAP						6	11		0.73
COL	Colombia	LAC	11	19	37	63	59	73	112	0.03	0.09
ZAR	Congo, Dem. Rep.	SSA	3	4	8		7			0.01	
COG	Congo, Rep.	SSA	8	9	21	61	62		34	0.03	0.02
CRI	Costa Rica	LAC	53	65	132	221	188	246	321	0.05	0.15
CIV	Cote d'Ivoire	SSA	8	12	35		54			0.05	0.05
CYP	Cyprus	WE			99	291	289	563	785		
CZE	Czech Republic	ECA				134			372		
DNK	Denmark	OECD	104	158	362	668	639	1139	1462	0.86	0.9
DOM	Dominican Republic	LAC			37	79	47				0.63
ECU	Ecuador	LAC	13	19	51	93	86	84	107	0.06	0.03
EGY	Egypt, Arab Rep.	MENA	9	6	30	26	26	49	52	0.02	0.02
SLV	El Salvador	LAC	25	25	66	63	75	43	101	0.07	0.14
ETH	Ethiopia	SSA					3	3	5		0
FJI	Fiji	EAP		42	108	162	124	172			
FIN	Finland	OECD	71	107	249	540	465	1015	1225	0.33	1.06
FRA	France	OECD	32	67	179	453	413	918	1216	0.92	1.07
GAB	Gabon	SSA	12	20	64	161				0.04	
GMB	Gambia, The	SSA		5	13	19					0.02
DEU	Germany	OECD	22	50	134	336	349	724	903		1.33
GHA	Ghana	SSA	6	14	20	25				0	
GRC	Greece	OECD	28	44	126	227	207	454	685	0.06	0.2
GTM	Guatemala	LAC	20	19	57	100	71	80	98	0.06	0.18
GNB	Guinea-Bissau	SSA		9	4						
GUY	Guyana	LAC		45	115						
HTI	Haiti	LAC		2	5						0.01
HND	Honduras	LAC	14	21	38	91	78	79	88	0.01	0.01
HKG	Hong Kong, China	EAP	68	119	197	485	505	1175	2233	0.09	0.21
HUN	Hungary	ECA		23	90	175	140	205	350		0.62
ISL	Iceland	OECD	115	140	632	857	766	1196	1362	0	0.11
IND	India	SA	1	1	3	4	4	5	6	0.06	0.24
IDN	Indonesia	EAP		2	11	18	20	30	44		0.18

IRN	Iran, Islamic Rep.	MENA			75						
IRQ	Iraq	MENA			69						
IRL	Ireland	OECD	78	127	345	904	875	1865	2687	0.17	1.57
ISR	Israel	MENA	47	87	212	340	377	782	1022	0.08	0.84
ITA	Italy	OECD	22	53	120	337	339	756	931	0.98	0.96
JAM	Jamaica	LAC			121	113	89	168	164		0.02
JPN	Japan	OECD	8	17	32	89	107	195	285	0.85	1.99
JOR	Jordan	MENA	24	23	67	222	189	213	216		0.19
KEN	Kenya	SSA		7	15	34	22	18	22		0.07
KOR	Korea, Rep.	EAP	9	14	57	113	148	324	488	0.08	1.22
KWT	Kuwait	MENA		102	226	485		146	690		0.02
LBR	Liberia	SSA		15	30	33					
LBY	Libya	MENA	34	50	159	361	209				
MDG	Madagascar	SSA	4	6	11	18	10	12	9	0.03	0.01
MWI	Malawi	SSA		2	7	10	5	10	10		0.01
MYS	Malaysia	EAP	19	23	53	139	130	227	420	0.07	1.58
MLI	Mali	SSA		1	4	6		11			
MLT	Malta	MENA	66	99	184	475	423	962	1283	0	
MRT	Mauritania	SSA	2	3						0.04	0.01
MUS	Mauritius	SSA		29	83	96	21	171	193		0.12
MEX	Mexico	LAC	19	19	39	93	81	95	177	0.11	1.2
MAR	Morocco	MENA	8	11	32	47	32	67	79	0.01	0.07
MOZ	Mozambique	SSA							6		0.06
NPL	Nepal	SA			0	1	3	4	2		0
NLD	Netherlands	OECD	107	204	484	1146	1062	1802	2550	0.83	0.89
ANT	Netherlands Antilles	LAC				898	675				
NZL	New Zealand	OECD	106	129	264	493	519	687	937	0.01	0.2
NIC	Nicaragua	LAC	39	36	81	119	84	27	48	0.03	0.18
NER	Niger	SSA	1	2	2	12				0.01	0.01
NGA	Nigeria	SSA	3	5	20		23			0	
NOR	Norway	OECD	95	146	349	651	564	1055	1340	0.19	0.29
OMN	Oman	MENA			79	124	225	260	278		
PAK	Pakistan	SA	5	8	6	17	16	22	26	0.09	0.06
PAN	Panama	LAC	36	45	86	131	124	145	175		0.01
PNG	Papua New Guinea	EAP			22		36	38			
PRY	Paraguay	LAC	4	6	10	23	21	33	51	0	0.03
PER	Peru	LAC	21	21	77	69	41	35	63	0	0.03
PHL	Philippines	EAP	7	9	24	33	19	39	47	0.01	0.52
POL	Poland	ECA				51	32	28	171		0.39
PRT	Portugal	OECD	23	46	88	214	157	452	658	0.15	0.47
QAT	Qatar	MENA			187	535	263	255			
ROM	Romania	ECA						45	68		
SAU	Saudi Arabia	MENA			69	386	344	351	373		0.02
SEN	Senegal	SSA	6	8	25	29		42	38	0.03	0.05
SLE	Sierra Leone	SSA			8						
SGP	Singapore	EAP	70	141	420	937	806	2435	3279	0.3	1.85
SLB	Solomon Islands	EAP		8	20	25	24				
SOM	Somalia	SSA		2	4	5					
ZAF	South Africa	SSA			73	148	100		193		0.21
ESP	Spain	OECD	21	37	97	174	157	505	732	0.18	0.5
LKA	Sri Lanka	SA	7	7	11	18	16	26		0	
SDN	Sudan	SSA	4	4	15	19	9		6		
SUR	Suriname	LAC	88					651	566		
SWE	Sweden	OECD	89	148	345	618	588	1049	1292	1.12	1.19
CHE	Switzerland	OECD	118	213	454	1143	1072	2161	2936	2.35	1.62
SYR	Syrian Arab Republic	MENA			62	109	105	53	59		
TZA	Tanzania	SSA							21		
THA	Thailand	EAP	4	9	19	38	33	75	138	0	0.98
TGO	Togo	SSA	3	4	13	21		33		0.02	0.01
TTO	Trinidad and Tobago	LAC		69	162	337	267	298	167		0.09
TUN	Tunisia	MENA	10	14	58	112	86	134	165	0.01	0.27
TUR	Turkey	ECA		8	31	53	53	92	150	0	0.15
UGA	Uganda	SSA									0.01
ARE	United Arab Emirates	MENA				584	454	616			

USA	United States	OECD	8	14	33	77	110	163	254	1.5	1.23
URY	Uruguay	LAC		24	68	116	65	116	125		0.07
VEN	Venezuela	LAC	48	56	135	204	154	124	153	0.02	0.03
YEM	Yemen, Rep.	MENA							9		0
ZMB	Zambia	SSA		11	40				8		0.03
ZWE	Zimbabwe	SSA					23	33	26		0.06

Note: Imports and RCA as explained in the text. Regional dummies are: EAP (East Asia and Pacific), ECA (East Europe and Central Asia), LAC (Latin America and the Caribbean), MENA (Middle East and North Africa), SA (South Asia), SSA (Sub-Saharan Africa) and WE (Western Europe).

Figure 1: Revealed Comparative Advantage in Technical Progress Diffuser Goods (1965-1995)

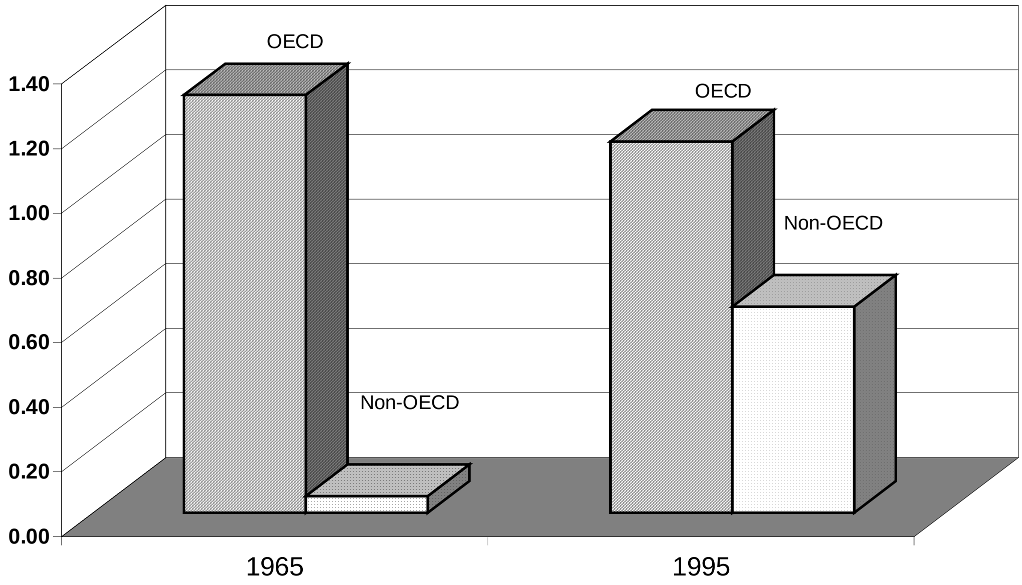

Figure 2: Technology Advantage and R&D Effort, 1995

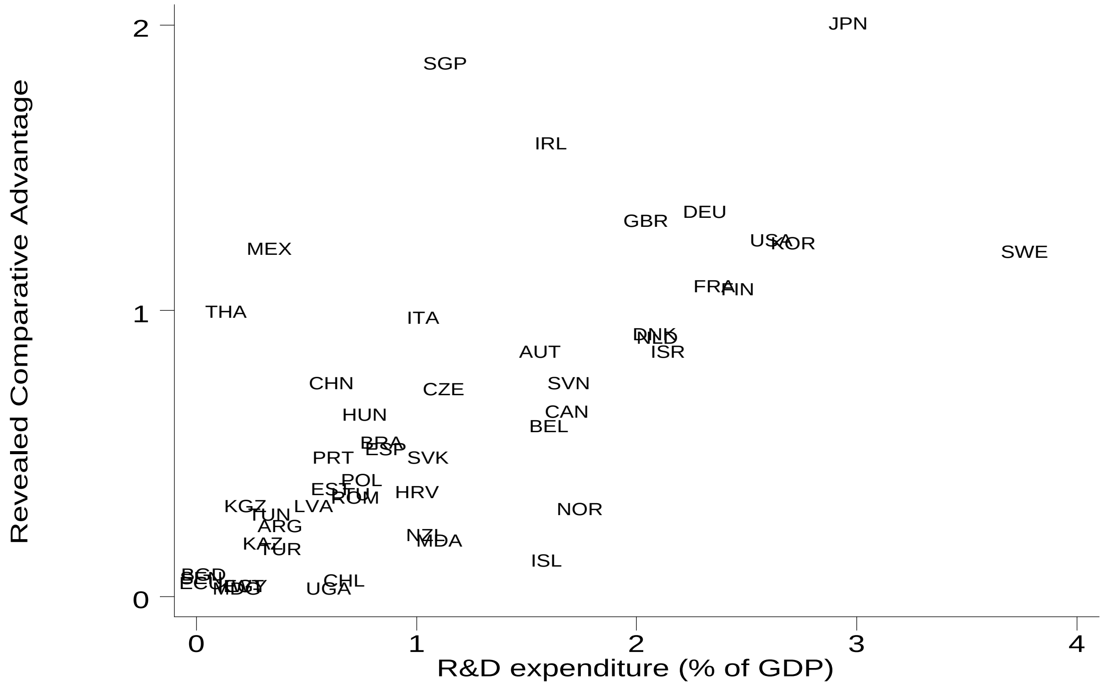

Table 1: Technology Adoption and Imports (1965-1995)

	1965	1970	1975	1980	1985	1990	1995
Total Sample							
Technology Imports	80	132	301	649	661	1400	2034
Technology Imports from OECD	31	42	107	248	234	411	537
Technology Imports from Non-OECD	49	90	194	400	427	989	1497
Manufacturing Imports	245	365	961	1988	1990	3676	5429
OECD							
Technology Imports	173	283	634	1242	1255	2816	3716
Technology Imports from OECD	62	102	253	537	510	1006	1368
Technology Imports from Non-OECD	111	182	381	705	745	1811	2348
Manufacturing Imports	533	854	1953	3859	3571	7794	9614
Non-OECD sample							
Technology Imports	41	87	213	467	450	880	1512
Technology Imports from OECD	17	23	70	167	148	215	268
Technology Imports from Non-OECD	23	63	144	300	302	665	1245
Manufacturing Imports	170	245	731	1573	1507	2344	3755
Technologically disadvantaged sample							
Technology Imports	72	116	263	536	522	1006	1319
Technology Imports from OECD	28	38	89	197	186	325	427
Technology Imports from Non-OECD	44	78	175	339	337	681	892
Manufacturing Imports	224	331	773	1435	1479	2805	4164

Note: Data in current US dollars per worker. See Appendix for details.

Table 2: Technology Adoption in Total Sample

	(1)	(2)	(3)	(4)	(5)
Log Investment per worker	0.179	0.185	0.139	0.123	-0.057
	(0.055)***	(0.056)***	(0.056)**	(0.056)**	-0.05
Intellectual Property Rights Protection Index	0.115	0.135	0.112	0.079	0.047
	(0.046)**	(0.047)***	(0.045)**	(0.047)*	-0.039
Sachs and Warner openness index	-0.123	-0.121	-0.148	-0.18	-0.182
	(0.055)**	(0.055)**	(0.054)***	(0.053)***	(0.046)***
Agriculture share (% GDP)	0.004	0.004	0.003	0.002	-0.003
	-0.004	-0.004	-0.004	-0.004	-0.003
Manufacturing share (% GDP)	-0.002	-0.001	0	-0.002	0.006
	-0.004	-0.005	-0.004	-0.005	-0.004
Land Locked country	-0.664	-0.65	-0.669	-0.625	-0.542
	(0.128)***	(0.130)***	(0.129)***	(0.131)***	(0.098)***
Primary Education Completed (% adult population)	0.019		0.02	0.024	0.023
	(0.009)**		(0.009)**	(0.009)***	(0.008)***
Primary Education Completed^2	0		0	0	0
	(0.000)**		(0.000)**	(0.000)***	(0.000)***
Log Exports and Imports per worker	0.654	0.67			
	(0.056)***	(0.057)***			
Primary Education (% adult population)		0.015			
		(0.007)**			
Primary Education^2		0			
		(0.000)**			
Secondary Education (% adult population)		-0.001			
		-0.007			
Secondary Education^2		0			
		0			
Higher Education (% adult population)		-0.017			
		-0.011			
Higher Education^2		0			
		(0.000)*			
Log Exports per worker			0.068		
			-0.08		
Log Imports per worker			0.637	0.605	
			(0.099)***	(0.088)***	
Log Manuf.Exports per worker				0.049	0.008
				(0.025)*	-0.022
Log Non-Manuf.Exports per worker				0.056	0.077
				-0.063	-0.051
Log Manuf.Imports per worker					0.706
					(0.055)***
Log Non-Manuf.Imports per worker					0.041
					-0.038
Observations	340	340	340	332	328
Number of countries	69	69	69	66	66
R^2	0.95	0.95	0.95	0.95	0.97

Notes: Dependent variable is the Log of Technology Imports per worker from OECD countries. Each regression has been estimated with a set of regional and time dummies. Standard errors are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 3: Technology Adoption in Non-OECD Sample

	(1)	(2)	(3)	(4)	(5)
Log Investment per worker	0.209	0.224	0.177	0.16	-0.005
	(0.059)***	(0.060)***	(0.060)***	(0.059)***	-0.054
Intellectual Property Rights Protection Index	0.12	0.13	0.117	0.063	0.029
	(0.047)**	(0.050)***	(0.047)**	-0.048	-0.04
Sachs and Warner openness index	-0.054	-0.053	-0.076	-0.111	-0.13
	-0.058	-0.058	-0.058	(0.057)*	(0.050)***
Agriculture share (% GDP)	0.002	0.004	0.002	0	-0.005
	-0.004	-0.004	-0.004	-0.004	-0.003
Manufacturing share (% GDP)	0.004	0.004	0.005	0.002	0.008
	-0.005	-0.005	-0.005	-0.005	(0.004)*
Land Locked country	-0.785	-0.757	-0.788	-0.733	-0.622
	(0.126)***	(0.126)***	(0.126)***	(0.121)***	(0.094)***
Primary Education Completed (% adult population)	0.009		0.011	0.018	0.014
	-0.012		-0.012	-0.012	-0.01
Primary Education Completed^2	0		0	0	0
	0		0	0	0
Log Exports and Imports per worker	0.577	0.583			
	(0.059)***	(0.060)***			
Primary Education (% adult population)		0.016			
		(0.008)**			
Primary Education^2		0			
		(0.000)*			
Secondary Education (% adult population)		0.002			
		-0.007			
Secondary Education^2		0			
		0			
Higher Education (% adult population)		-0.001			
		-0.02			
Higher Education^2		0			
		-0.001			
Log Exports per worker			0.058		
			-0.085		
Log Imports per worker			0.56	0.592	
			(0.102)***	(0.090)***	
Log Manuf.Exports per worker				0.053	0.016
				(0.026)**	-0.023
Log Non-Manuf.Exports per worker				-0.014	0.024
				-0.067	-0.055
Log Manuf.Imports per worker					0.681
					(0.059)***
Log Non-Manuf.Imports per worker (US $)					0.035
					-0.041
Observations	285	285	285	277	273
Number of countries	57	57	57	54	54
R^2	0.94	0.94	0.94	0.95	0.97

Notes: Dependent variable is the Log of Technology Imports per worker from OECD countries. Each regression has been estimated with a set of regional and time dummies. Standard errors are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 4: Technology Adoption in Technologically Disadvantaged Sample

	(1)	(2)	(3)	(4)	(5)
Log Investment per worker	0.219	0.206	0.184	0.163	-0.014
	(0.062)***	(0.062)***	(0.063)***	(0.063)***	-0.057
Intellectual Property Rights Protection Index	0.122	0.139	0.12	0.076	0.024
	(0.050)**	(0.051)***	(0.050)**	-0.052	-0.045
Sachs and Warner openness index	-0.072	-0.078	-0.098	-0.139	-0.166
	-0.059	-0.06	(0.059)*	(0.058)**	(0.052)***
Agriculture share (% GDP)	0.004	0.005	0.003	0.001	-0.003
	-0.004	-0.004	-0.004	-0.004	-0.003
Manufacturing share (% GDP)	0.002	0.003	0.003	0	0.008
	-0.005	-0.005	-0.005	-0.005	(0.005)*
Land Locked country	-0.688	-0.679	-0.69	-0.645	-0.539
	(0.120)***	(0.119)***	(0.121)***	(0.123)***	(0.099)***
Primary Education Completed (% adult population)	0.023		0.024	0.029	0.027
	(0.010)**		(0.010)**	(0.010)***	(0.008)***
Primary Education Completed^2	-0.001		-0.001	-0.001	-0.001
	(0.000)***		(0.000)***	(0.000)***	(0.000)***
Log Exports and Imports per worker	0.61	0.641			
	(0.062)***	(0.063)***			
Primary Education (% adult population)		0.02			
		(0.008)**			
Primary Education^2		0			
		(0.000)**			
Secondary Education (% adult population)		-0.004			
		-0.008			
Secondary Education^2		0			
		0			
Higher Education (% adult population)		-0.018			
		-0.012			
Higher Education^2		0			
		(0.000)*			
Log Exports per worker			0.071		
			-0.086		
Log Imports per worker			0.581	0.611	
			(0.105)***	(0.094)***	
Log Manuf.Exports per worker				0.046	0.005
				(0.026)*	-0.024
Log Non-Manuf.Exports per worker				-0.006	0.049
				-0.071	-0.06
Log Manuf.Imports per worker					0.706
					(0.062)***
Log Non-Manuf.Imports per worker					0.044
					-0.041
Observations	297	297	297	289	285
Number of countries	62	62	62	59	59
R^2	0.95	0.95	0.95	0.96	0.97

Notes: Dependent variable is the Log of Technology Imports per worker from OECD countries. Each regression has been estimated with a set of regional and time dummies. Standard errors are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

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[1] Between the vast amount of technological structures classifications available; this one is based on Pavitt (1984), Guerrieri and Milana (1990) and ECLAC (1996). In Table A1 in the Appendix, the reader can find a brief description of the capital and intermediate goods selected.

[2] See Caselli and Coleman (2001) for a more detailed discussion. In short, when the sample size is large enough and heterogeneous, the RE estimator is the most efficient one but it is just consistent under the assumption that u^j is uncorrelated with the explanatory variables. The FE estimator assumes that the country effect is well explained by introducing a country dummy without any distribution. However when the countries are heterogeneous the country dummy would absorb too much noise and the FE estimator would be inefficient.

[3] At the 10 per cent level of significance.

[4] At the 10 per cent level of significance.

[5] At the 10 per cent level of significance.

[6] Grossman and Helpman (1991) provide a good discussion on a collection of theoretical models.

[7] Coe and Helpman (1995) for OECD countries, and Coe et al. (1997) for Non-OECD countries, among others.

[8] I have tested this hypothesis using the alternatives primary, secondary and tertiary educational level measures.

[9] North (1981) stress the role of the legal system to define the basic incentives of creative people to develop new technologies in a historical context. Romer (1990) use the same idea to justify the assumption that technological properties of the goods and the legal system determine the degree of excludability, and hence the existence of knowledge and technological externalities.

[10] Rodriguez and Rodrik (1999) document the sensitivity of growth-trade regressions to improvements in the methodology of the SW index calculation.