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Technology Diffusion Through Trade

- growth possibilities for developing countries

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Abstract

In this thesis recent data on trade between 23 OECD countries and the non-OECD countries, singling out six low or lower middle income countries (Brazil, China, India, Indonesia, Philippines and Thailand), is examined to detect possible technological diffusion which might, according to recent theories on economic growth, lead to an increased growth in the countries in question.

Data on total trade and trade in machinery and equipment, an economic sector that is much likely to contain a large amount of technology, is collected and studied in order to see how this might indicate a facilitation of technological spillovers. Further, data on research and development is added to the survey to calculate some measures on possible technological diffusion and to see if there is a difference in the indication of growth given what measure one chooses to use. Finally data on education is presented to see how the human capital, which is an important factor for growth and which is important for the requisition of the possible technology diffusion that takes place, can indicate possibilities for higher growth in the six developing countries included.

The results presented show that all data, irrespective of which measure one chooses to use, points towards an increase in growth and facilitation for technological diffusion between the OECD countries and the developing countries included in the study. There are some differences in the level of the increases but over all there is a positive picture regarding possible technological spillovers and growth. Also when it comes to data on human capital, here presented as average years of schooling, it points towards a positive development for the six different countries. However, a faster increase in average years of schooling might be desired for one of the developing countries, namely China, and a higher level of education for another, Brazil.

Key words: Economic Growth, Technological Diffusion, Trade, Developing Countries

Table of content

1 Introduction

Technology has long been seen as an important ingredient to economic growth. Earlier economic growth theories have viewed technology as an exogenous force, something that could not be affected by the factors in the model, but recent research has included technology in the theories as an endogenous and changeable factor. What then is technology? It may not be too easy to define but one way of describing it which is frequently used in economic studies is that it is a measure of the different governments' expenses on research and development. When only using this measurement one might assume that growth will be spread quite unevenly throughout the world. This as, according to the Science and Engineering Indicators 2006, presented by the US National Science Board, 82% of the research and development in year 2000 was conducted in the OECD countries and it is safe to assume that theses are the countries that spend the most in this area. How will then the developing world be able to receive technology and gain economic growth? Both economic theory and several empirical testing have concluded that there are possibilities for technology to spread over the borders. This could for example be trough trade, foreign direct investment, scientific journals or international conferences. The first two have been studied the most since these are the easiest to find suitable measures for that are possible to analyse. When looking at trade, there has been a long debate about the gains from a freer, more open trade, first and foremost for the developing countries. One of the first advocates for this idea was the economist Adam Smith, as early as in the 18th century. Turning to economic growth theory, and especially this of technology diffusion, it is possible to find much evidence that supports this idea. But what is the picture while turning to recent trade data? If comparing recent trade data with what one can learn from economic growth theory, is it possible to see any tendencies that developing countries might gain from their involvement in trade with developed countries? Has the recent period of strong globalization been in accordance with what one can believe be positive for technology diffusion and the growth process in countries that are quite dependant on the technology that is produced in the technologically more advanced part of the world, often seen as the OECD countries? These are the questions that lie as a background for this thesis and that will be further elaborated in the following parts of this thesis.

1.1 Purpose

The purpose of this thesis is to study the trade between 23 OECD countries[1] and the non-OECD countries, singling out six developing countries for a deeper examination, with the intent to see how trade has affected the non-OECD countries access to the technological research and development conducted in the OECD countries. The six developing countries chosen are Brazil, China, India, Indonesia, Philippines and Thailand. The study will stretch over a time period of 11 years when there has been a rather high rate of globalisation, namely between the years 1990-2000. One could benefit from doing a study that surveys a longer period of time, but due to lack of data I have chosen this time span.

Since the way of measuring technological transfer might differ given what method one uses, I will in this thesis present three different ways of measuring technological spillovers in order to give a better picture and to see if there are any difference between them regarding the indication of possible technological transfer.

The key questions that will be answered in this thesis are:

(i) Has the latest years of globalization benefited non-OECD and developing countries when it comes to technology diffusion and growth?

(ii) Is there a difference in the conclusion one can make regarding possible technology diffusion given what measurement one chooses to use?

1.2 Methodology and Data

The method used in this thesis will be a careful examination of theories explaining growth through technology acquisition and earlier research made on technological spillovers between countries. There will also be a close survey of trade statistics to see how R&D might be transferred between developed and developing countries.

[1] Luxembourg is excluded due to lack of satisfying data

The trade between the countries will be presented by the export from the OECD countries to the non-OECD countries, alternatively the six developing countries. I will then further break down trade into different sectors and look at the sector that is most likely to contain a great deal of technology that can be transferred by these types of goods, namely the exports in machinery and equipment. Further I will survey the expenditures on R&D in 17 of the OECD countries in question and see how this has changed during this time period[2]. With this data I will create three different measurements of technological diffusion from the OECD countries to the six different developing countries and see if there is a detectable difference between those. The three measures are based on the total R&D stock existing in all the OECD countries combined, the different R&D stocks weighted by the share of import and finally, the intensity of trade between the OECD countries and the six developing countries. Finally I will also study the rate and quality of education in the six developing countries singled out in this thesis since education is very important for the acquisition of technology.

Data for the total amount of trade, trade divided into different sectors and the R&D expenditures are gathered from the OECD statistical database, the Structural Analysis Database, STAN. Trade data are collected from the STAN Bilateral Trade Database Vol 2006, release 01 and the industry list is based on ISIC Revision 3. The R&D expenditure data is obtained from the ANBERD, found under the OECD STAN database, which contains industrial R&D expenditures also classified by ISIC Revision 3.

When calculating the technology diffusion, the R&D stock for the different OECD countries may be made in several different ways. Due to a limiting data access, I have used the countries R&D expenditures, taken from the ANBERD database and summed up the three previous years of expenditures plus the year in question and by this created a R&D stock used for further calculations.

Educational data are obtained from the Barro- Lee database (2000) that contains a great deal of different educational data. The measure used in this thesis for the level of education is the average years of schooling in the different countries. This might give an indication of how well educated the population in each country are in average and give a hint of the possibilities to incorporate the technological spillovers.

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[2] Due to lack of data I am forced to exclude some of the countries

To get comparable data over the years I have recalculated the amounts given into constant prices so that all amounts are shown in the price level of the year 2000. This by using a GDP deflator taken from the OECD Factbook 2006: Economic, Environmental and Social Statistics (2006).

1.3 Delimitations

There are many different ways for technology to spread across borders. It could be by trade, foreign direct investment (FDI), various technical journals, international conferences or students that choose to study abroad. There is however a lot of problems concerning data for many of these variables. The scope of this thesis is to single out trade and investigate how technology might be incorporated in this factor. The measurements and data for the different variables used in this thesis are carefully considered and evaluated, though there are many possibilities to choose other measurements and make use of other databases. However, the ones presented in this thesis are well suited for this type of study.

The same goes for the measure of human capital. In this thesis, the average years of schooling is used because it is often used while performing this type of study and it gives a good initial picture of the skill level of a country's population. There is however other measures that might be included in this type of studies but since it does not lie as the base for this thesis they are left aside.

When it comes to the choice of the six low or lower middle income countries singled out in this thesis, the choice has been based mainly on data access. The six counties chosen were the ones that were included with bilateral trade data in the OECD's STAN Bilateral Trade Database. One must bear in mind that these countries might not be representatives for all the developing counties throughout the world but they have the advantage of representing different areas of the world.

1.4 Disposition

The remainder of this thesis is organised as follows. In the next section the theoretical framework will be presented and examined. Section 3 will contain a close survey of the previous research concerning technological spillovers and the ways those might take. In the fourth section current data on trade, R&D expenditures and three different measures on technology diffusion as well as education will be closely examined to distinguish the patterns and the possibilities of technological spillovers and growth for the developing countries. The final section concludes and gives suggestions for further research.

2. Theoretical Framework

In this part, the theory that will constitute the framework for this thesis will presented and thoroughly examined. It consists of recent economic growth theories that focus on technology and technological diffusion. There will first be a theoretical explanation to what technology might be and thereafter some recent theories with endogenously technology will be put forward and closely examined. The connection between trade and economic growth will also be presented. This will later in the thesis be connected with empirical testing and the questions that are meant to be answered in this study.

2.1 Technology

A good way to begin is to sort out what we mean by technology. One definition of technology given by Charles Jones (2002, p. 79) is: *"technology is the way inputs to the production process are transformed into output"*. In other words how a given amount of inputs are used to produce goods and services. The basis behind technology is knowledge. It is the ideas that push technology forward. Knowledge and technology do carry some different characteristics than most other economic goods. They are nonrivalrous and they have a varied degree of exclusion. (Jones 2002, p 80f) The nonrivalrousness mean that when an idea has been created there is nothing (in theory) that stops someone else who has knowledge of that idea to use it. It is also difficult to exclude people from using ideas once they have been created. There are however practical ways to hinder people from taking advantage of the public nature of ideas, for example patent laws and copyrights. A patent protects researchers and make it profitable to produce ideas when otherwise it would be difficult to motivate spending money on research. The production of ideas does usually include a high initial cost but low marginal costs. Combined with the public good character of ideas there are difficulties in making profits. This makes the economics of ideas contain increasing returns to scale which is closely tied to imperfect competition. That is, if a proportional increase in the inputs in the production creates an output that is more then proportionately there are increasing returns to scale. (Nicholson, 2005, p. 190f) This arises since there is an initial high cost of the production of ideas but the average costs are low. It is also this that creates the imperfect competition. This makes it necessary with some kind of protection for the researchers, for example in the form of a patent law.

There is also a difficulty in measuring ideas since these are very abstract. One way is to count patents but not all ideas are patented. Ideas does also tend do build on other ideas and a lot of them are just small adjustments of something already created. In this thesis technology will be measured by the different governments' expenses on R&D since this is a good measure of technology to use while doing this type of research.

2.2 Endogenous Growth Theory

Technology has long been looked at as very important for growth. Neoclassical growth theory calls it the "engine of economic growth" (Jones 2002, p.96). In the earlier developed models technology was exogenous, that is, there were nothing in the model that explained technological progress, this happened automatically outside the model.[3] Instead it was mainly capital accumulation that was the endogenous driving force of growth. This was not to satisfaction for many researchers because there was a thought that technological progress occurred because there were profits to be made. (Jones 2002, p. 97) Theories started to develop where technology was instead considered endogenous.

Paul Romer contributed to this view in the beginning of the 1990 when he elaborated his endogenous growth theory.[4] In his model he has incorporated technological progress as the main source of growth. The idea is that researchers who are interested in making profits from developing new ideas are included in the model. (Jones 2002, p. 97) The production function of Romer's model is quite like the earlier famous Solow model:

$$Y = K^{\alpha}(AL_y)^{1-\alpha}$$

In this Cobb- Douglas production function K stands for the capital stock, L_y stands for labour that are engaged in production of goods and services (as opposed to the labour engaged in research and development) and A is the stock of ideas. The parameter α denoted the shares divided between the inputs and it is a number between 0 and 1. All these inputs are used to produce output Y (often referred to as GDP). (Jones 2002, p. 98) The news in this growth

[3] See for example the Solow model (Jones, 2002, p. 36ff.)
[4] See for example Romer 1988, 1990

model is as mentioned earlier that technology is also an input into production and that this will create increasing returns to scale due to the economic nature of ideas mentioned earlier as opposed to constant returns to scale that for example the Solow model implies (Jones, 2002, p. 22).

The technological development in the model is expressed by a production function for new ideas. Change in the stock of technology is illustrated by $\dot{A}$[5] and the production function taken from Jones (2002, p. 100) that describes the Romer model is given as:

$$\dot{A} = \delta A^{\phi} L_A^{\lambda}$$

where δ stands for the general productivity in the research sector, λ is a parameter with a value between 0 and 1 and indicates that there are decreasing returns to the development of new technology. L_A is the labour engaged in research and development and φ is a parameter that shows in which degree new ideas build on old ideas. If $\varphi > 0$ new ideas give a positive contribution to those already existing and if $\varphi < 0$ one can say that the easiest ideas are already created and that it is now more difficult to develop new. Should $\varphi = 0$ it would mean that the productivity of research does not depend on the earlier stock of knowledge. (Jones, 2002, p 99f) Thus, technological progress depends on the amount of labour engaged in research and development and the productivity in the R&D sector.

Other things than technology that affects the growth in the model is the accumulation of capital, K, and the growth of the labour force, L[6]. The equation for capital accumulation is the same as for example in the earlier Solow model and is given by (Jones, 2002, p.99):

$$\dot{K} = s_K Y - dK$$

where the s_K stands for the share of GDP (Y) that are saved, which is the same as to say that $s_K Y$ corresponds to the investment made, and the d is the depreciation rate of the capital. The growth in the labour force is illustrated by (*ibid.*):

[5] The dot henceforth represents change in a parameter
[6] Which is equal to the growth of the population in this model

$$\frac{\dot{L}}{L} = n$$

The news in this endogenous growth model is as shown above the inclusion of technology as a producer of growth just as capital accumulation and the growth of the labour force. This shows the importance of the further elaborated technology diffusion by, for example, trade directed towards those countries that might not be able to produce much technology themselves. Those equations might further be used to solve the model for its so called "steady state" which means when all the factors in the model remain constant and growth occurs at a steady pace. (Jones, 2002, p.29) but this lies outside the scoop of this paper and will not be treated.

2.3 Technology Diffusion Model

In Jones (2002) Charles Jones present a model which takes into account that technology might spread between countries and where growth depends on how able a country is to take advantage of the given technology. The model builds on the earlier described Romer model but the difference here is that it is the level of human capital that is important for growth, not the production of technology. Technology in the model is seen as a frontier which level is in line with the highest developed technology in the world. The production function in this model is given by (Jones, 2002, p.125):

$$Y = K^{\alpha} (hL)^{1-\alpha}$$

where the basics are the same as the Romer model, but instead of technology, an h that stands for the amount of human capital is included. Here it is the human capital that gives the model its increasing return to scale.

When it comes to growth the capital accumulation and the change in labour are the same. The growth in human capital can be described as the skill amongst the individuals contributing to the economy and is illustrated by (Jones, 2002, p. 126):

$$\dot{h} = \mu e^{\psi u} A^{\gamma} h^{1-\gamma}$$

Here the *A* stands for the technological frontier mentioned earlier. The μ represent the overall productivity in the acquisition of human capital, the ψ is the amount of human capital that is acquired per year in education, in other words, the quality of the education, and the parameter γ measures how important the world technology is compared to the human capital. If γ is large then the world technology is more important and if it is small then the human capital is more important. This parameter is always somewhere between 0 and 1.

Since the world technological frontier is the same for all countries in the model, the differences in growth will lie in the amount of human capital and the productivity and quality of the same. If the country is far from the technological frontier; i.e. the *A* is much higher than the *h*, then the rate of growth will be higher because it is easier to learn the not too advanced technology. If the skill level, *h*, is closer to the world technological frontier then it is more difficult to learn the advanced technology and growth will slow down until it adjusts with the growth in the world technology (Jones, 2002, p. 127).

This endogenous growth model presents the importance of a countries human capital in the procedure to take advantage of the existing technology in order to produce growth. This might connect the growth process to, for instance, the level and quality of the education in a country and its importance for the acquisition of the technology offered by trade with more technologically advanced countries.

As the earlier presented endogenous growth model the equations given might be used to solve the model for its "steady state" level but this will not be treated any further in this thesis as it is not of importance for the further analysis.

2.4 Trade and Growth

Gene Grossman and Elhanan Helpman have, in their book Innovation and Growth in the Global Economy (1991), presented some theories regarding technological progress and trade, both important for growth in the world economy. They take the earlier presented models and apply theses in a global environment where trade and interaction between countries becomes additional components. They stress the importance of a country's involvement in the global economy for the innovation and growth:

> *"…a country that interacts with the outside world may gain access to the large body of knowledge that has already been accumulated in the international research community, as well as to some of the new discoveries that are being made there"*(Grossman, Helpman, 1991, p.166)

It is therefore important to examine how much of different countries' investment in R&D that can be transmitted to other countries for example through trade.

Grossman and Helpman identify four different ways where trade might enhance the growth of a country. First, trade is a way to communicate and exchange information that facilitates the spread of technology. Second, the competition that trade carries might promote investment in research and pursue countries to produce new and better ideas. A third effect is the enlargement of the market that comes with trade. Finally there might be a positive (or negative) reallocation of resources to research when a country opens up for trade. (Grossman, Helpman, 1991, p. 237f) Some of these effects can be attained from other sources than trade, like for example scientific journals, foreign direct investment, scientific conferences etc. but that lies outside the scope of this paper and will not be analysed.

The fourth effect of trade on innovation and growth is likely to take place when it comes to countries that are dissimilar. If a country is relatively poorly endowed with human capital, its rate of innovation will not fall if being engaged in trade since that country will have a greater access to human capital from the world market. It is also so that an increase in human capital which does not cause a decline in the relative abundance of that factor might increase the rate of innovation in the long perspective. (Grossman, Helpman, 1991, p.256) If, however, a country is instead rich on unskilled labour, there might be a risk that trade makes this country specialise in traditional manufacturing or other areas that do not require high skilled labour and this might lead to a fall in growth in non traditional manufacturing even though they have access to the world technology progress. (Grossman, Helpman, 1991, p. 257) One can here see the importance of having a well educated human capital so it is possible to avoid this fall in growth.

3 Previous Empirical Research

This chapter will present and thoroughly examine some of the most cited and well known empirical studies made on technology diffusion through trade. There have been two distinguishable features of this type of research to be found, one that has been directed towards technological spillovers between developed countries, mainly the OECD countries, while another direction has been towards developing countries, showing if and how they can take advantage of the research and development taking place in developed countries.

3.1 Research Concerning Developed Countries

Since the theories regarding endogenous technological growth and technological diffusion between countries have seen the light of day there has been a great deal of empirical testing of those theories. One of the first was David Coe and Elhanan Helpman (1995) which tested the extent of technological spillover between developed countries and the effect this had on the total factor productivity of the countries during the years 1970-1990. The two implications tested was: (i) how much the countries' domestic R&D stock has an impact on the countries' total factor productivity and (ii) if there are technological spillovers from trading partners R&D stock and how this affects the total factor productivity in the home country. They used a panel of 21 OECD countries plus Israel[7] and they specified a regression equation containing a measure of the domestic R&D and foreign R&D from their trading partners and tested this with the Ordinary Least Squares- estimator (the OLS- estimator). The measure of R&D is based on the expenditure on this area in the different countries and then the foreign R&D it is multiplied by the weighted import from the trading country in question. Their specification can be illustrated as follow:

$$\log TFP_i = \beta_i^0 + \beta_i^d \log R\&D^d + \beta_i^f m_i \log R\&D_i^f$$

[7] Countries included in the study was: United States, Japan, West Germany, France, Italy, UK, Canada, Australia, Austria, Belgium, Denmark, Finland, Greece, Ireland, Israel, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden and Switzerland.

where TFP_i is the total factor productivity of country *i*, the $R\&D^d$ is the domestic spending on research and development and the $R\&D^f$ is the trading country's spending on that area. The *m* stands for the share of imports from the foreign country.

The results presented by Coe et al. (1995) were that both domestic and foreign R&D stocks had significantly positive impact on a country's total factor productivity. It is also shown that foreign R&D may have an even larger effect on productivity the more open a country is to international trade. The same result goes for a small country as opposed to a larger country that has more benefit from its own domestic R&D stock. (Coe et al., 1995, p. 875) These results are not very surprising because a larger country might have a higher possibility to perform more research and development than a small country. What is significant in this study is the evidence of the strong impact the international technological spillovers have.

The findings of Coe et al. (1995) were much commented and they have also been criticised by Wolfgang Keller (1998) in a paper where he proposed that the trade patterns were not important for the result. Instead he created randomly chosen trade patterns and measured the results using a Monte-Carlo robustness test. He uses the same countries as Coe et al. (1995) and the same specification of the tested equation. In his results he discovers that the randomly chosen trade patterns give a just as positive effect in the total factor productivity and that it therefore does not matter how much trade one country has with another specific country but it is the amount in total. When looking at the R^2measure[8], the randomly chosen trade patterns show an even better fit. (Keller, 1998, p.1475) He concludes that the composition of imports from other countries plays no role in the impact foreign R&D has on the total factor productivity.

David Coe and A.W. Hoffmaister do however give a response to Keller and the results he presents. In their article "Are There International R&D Spillovers Among Randomly Matched Trade Partners? A Response to Keller" (1999) they question Keller's way of constructing his random trade patterns and they argue that what he call random trade patterns are in fact average weights with a random error. (Coe et al., 1999, p.13) Instead Coe et al. (1999) use an alternative method to create these random trade patterns and while doing so they conclude that there is in fact no positive international R&D spillovers when using randomly chosen

[8] The R^2 measure denotes the percentage of variation in the dependent variable accounted for by the independent predictor variables.

trade patterns, and that countries growth in total factor productivity is connected with its trading partners level of R&D.

After these papers there has been a flow of responses and testing of this subject. One paper that builds on the testing of Coe et al. (1995) is the one that Gwanhoon Lee (2005) presents. He uses the same regression equation as Coe et al. (1995) but he tests it with improved econometric techniques. Instead of using the OLS estimator, Lee uses the Fully Modified Ordinary Least Square estimator (FMOLS) (Lee, 2005, p. 252). Another difference is that he uses only 17 OECD countries where Coe et al. (1995) used 22 countries[9]. Instead, Lee has increased the number of years tested from 1970-1990 to 1971-2000.

The results given by Lees testing of the improved FMOLS estimator are similar to those by Coe et al. (1995), which is that the effect of other countries engagements in R&D and the spillovers from that in trade is significantly positive. This strengthens the validity of the earlier results given by Coe et al. (1995).

There is also another study that takes off in the findings from Coe et al. (1995). It is Rod Falvey, Neil Foster and David Greenaway (2004) who, instead of just measuring the effects of foreign knowledge spillovers through imports, also measures the effects of foreign knowledge spillovers through exports. They argue that knowledge embodied in exports comes in the form of learning by doing. (Falvey et al., 2004, p. 210) This study does contain 21 OECD countries[10] and includes the years 1975-1990. Falvey et al. (2004) ad another factor to their testing. They investigate whether the nature of the foreign knowledge does matter, i.e. if it matters whether the knowledge is a public or private good. In their results they find out that when it comes to knowledge embodied in imports, the nature of the knowledge does not matter. There are positive spillovers from imports both when it is of private and public nature. (Falvey et al., 2004, p. 211) When it comes to exports, the results are a bit more ambiguous. The best result from exports is given when the foreign knowledge is a public good and when the exports spillovers also are considered a public good. (*ibid.*) Hence the knowledge spillovers from exports are more difficult to attain then that from imports.

[9] Lee excludes Greece, Israel, New Zealand, Portugal and Switzerland.
[10] They use the same countries as Coe et al. except for the exclusion of Israel.

3.2 Research Concerning Developing Countries

Another influential and much commented paper given the subject that has also been produced by David Coe, Elhanan Helpman and A.W. Hoffmaister is "North- South R&D Spillovers" (1997) and this paper investigates the possible technological spillovers during trade between developed and developing countries and the effect this have on the developing countries total factor productivity. They do also examine how a raise in the spending on R&D in all of the developed country together as well as each country alone affects the group of developing countries. In this paper, 77 developing countries are tested for the same period of time as the test done on the OECD countries. The regression equation do not, as the earlier equations, include the domestic R&D measure for the developing countries since during the year for the testing of the hypothesis, 96% of the research and development in the world took place in the developed countries. Instead they have included a measure for human capital, namely the higher secondary school enrolment rate, which, as seen before in the technology diffusion model, is important for growth. The measure for the foreign R&D is the same as that in the earlier paper, "International R&D Spillovers" (1995) and is multiplied by the import share of the trading country. The estimated equation is thereby illustrated by:

$$\log TFP = \beta^0 + \beta_i^f m \log R\&D_i^f + \beta_i^d EDU_i^d$$

where the EDU^d stand for the secondary school enrolment rate in country *i.* The rest of the measures are the same as the ones they used in the study from 1995.

The results that Coe et al. (1997) presents are that there is significant technological spillovers from developed to developing countries. They also show that an increase in the developed worlds spending on R&D by 1% will raise the output in the developing countries by 0.06%. When broken down into individual countries, the USA was the country which spending on R&D influenced developing countries the most in this study. An increase in the R&D spending in the USA by 1% alone raised the overall productivity in the developing countries by 0.03%. (Coe et al., 1997, p. 147) Coe et al. (1997) also mention Japan, Germany, France and United Kingdom as important providers of technological spillovers. They also take geography into consideration and point out that Africa trade most with Europe and would therefore receive most technology from the European countries, while the Asian countries and

Latin America are most likely to receive their technology from Japan and the USA respectively (Coe et al., 1997, p. 148).

Another interesting study has been made by Maurice Schiff and Yanling Wang (2004) where they not only look at the knowledge spillovers between countries, but also if it is the quality or the quantity of the knowledge that is the most important. In other words, if it is the content of R&D in the imports (quality) of the degree of openness to trade (quantity) that gives the highest effect on the total factor productivity of a country. In their study they use both developed and developing countries in order to see if there might be a difference between the two groups. Therefore Schiff et al. (2004) includes two measures in their regression equation, one for openness to trade constructed by the rate of imports divided by the GDP, and one for the content of the R&D stock constructed by the trading partners stock of R&D.

The findings of Schiff et al. (2004) is that openness to trade plays a larger role for growth through knowledge spillovers than the content of the trading partners R&D stock for developing countries. The opposite goes for the developed countries. There it is the content of the trading partners R&D stock that gives the highest positive result and the openness to trade plays the minor role. The conclusion that can be drawn from these results is that trade liberalisation for developing countries can be an important factor for growth. (Schiff et al,. 2004, p. 17f)

An alternative idea concerning technology diffusion is analysed by Jörg Mayer (2000) where he considers the possibility earlier presented by Daron Acemoglu and Fabrizio Zilibotti (1999) that the worlds most advanced technology might be difficult for the human capital in a developing country to absorb and that it might be easier for this country to apply a less advanced technology first. Mayer investigates this by looking at machinery imports to different sectors of the economy, e.g. agriculture, mineral, low skilled labour, scale and skilled labour and resource and high skilled labour, and the technology diffusion to those sectors.

Mayer follows the same structure as Coe et al. (1997) with a few exceptions. The imports are not weighted by the R&D stock of the foreign country but he simply uses the import averages. He argues that the developing country is affected by the level of technological progress of the trading partner and not the intensity of the relationship. Therefore it is not important where the most part of the imports comes from but it is the imports as a whole and one can put them all together and use the imports averages.

Another difference is that, unlike Coe et al. (1997) Mayer includes the impact from other developing countries technological import not just that from the OECD countries and this is an important difference when one wants to examine if less advanced technology is easier to attain than higher developed technology. Finally, he does break down the imports into different industries instead of using it all together as Coe et al. (1997) does.

The results brought forward by Mayer (2000) are that the importance of technological imports from other developing countries, named “technologically more advanced developing countries” (Mayer, 2000, p. 2), is small compared to the impact of the imports from developed countries, but it has substantially increased over the years. The technology from the sectors of general- purpose industry is the most important imports from developed countries but the technology imports from the more specialized industrial sectors from the technologically more advanced developing countries plays a more and more important role for the less developed countries. (Mayer, 2000, p. 22) He also concludes the importance of having a well educated labour force to be able to benefit from the technology spillovers in the international economy. To sum up, Mayer turns to the example of the East Asian development experience were they successfully made the industrial environment grow at the same time as they made massive expansions in the educational system. This made it easier for the East Asian country to keep the technological gap smaller and lead to higher growth.

One conclusion that can be drawn from the empirical studies presented above, both those concerning developed countries and those concerning developing countries, is that there are, in most cases, technological spillovers through trade. According to Schiff et al., openness to trade are more important for the developing countries than the actual R&D content of the spillovers, while Mayer concludes that less developed countries might have better use of the technological spillovers from their more advanced developing countries instead of a country that are to highly developed. The common conclusion points however towards the importance of trade regarding technology diffusion between countries.

4 Measures on Possible Technological Spillovers

In this chapter, data regarding trade from the OECD countries to the non-OECD countries and in particular six selected developing countries will be closely examined with the intent to determine if the non-OECD and developing countries may have had the possibility to gain from trading with the more technologically advanced OECD countries. The data will be put in connection with the earlier presented growth theories and empirical research. Data concerning the R&D expenditures from the different governments of the OECD countries will also be presented and examined from the angle of economic growth and there will be a presentation of three different ways to measure the possible technological diffusion. There will also be a presentation of some data regarding the educational levels in the six developing countries which are singled out from the rest of the countries. Finally the change in the six developing countries GDP levels per capital will be shown to give a concluding estimation of possible signs of technological transfer.

4.1 Total Trade

In the study of Schiff et al. (2004) they conclude that the quantity of trade, i.e. the degree of openness to trade is the most important for developing countries when it comes to their ability to profit from international R&D spillovers. Coe et al. (1995, 1997) also use the total sum of imports while conducting their studies of technology diffusion. Their results agree with those of Schiff et al. (2004) that the amount and directions of trade is important for growth. It might therefore be interesting to investigate how much the developed countries do export to the developing countries in this study and also see how this has changed over the period over 11 years included in this study, from 1990-2000. If it has increased it might be an indication of an increased growth in the developing countries in question.

In the OECD statistical database STAN one can gather data regarding the exports from 23 of the OECD countries[11] to the non-OECD countries of the world. Put together in a table the result will be as shown in the table in Appendix 1A. To get comparable results, the amounts in the table are presented in PPP adjusted dollars which has been recalculated into constant

[11] Luxembourg is excluded due to lack of satisfying data

prices so that all amounts are shown in the price level of the year 2000 using a GDP deflator taken from the OECD Factbook 2006 (OECD, 2006a).

The overall impression of this data is that trade from OECD countries to non- OECD countries has increased in most of the countries accounted from the year 1990 to 2000. This is easy to see if one looks at the total amount of export at the bottom of the table. One clear trend is however that the export seems to be at its highest around the years 1995-1997 and after those years it goes noticeable down. In the last columns of the table the numbers seem to have recovered some and there seems continue positively in the year 2000. This decline in export might reflect the crisis in both the financial and the trade market in the late 1990, which according to the UN World Economic Situation and Prospects for 1999 report, was due to increased risks and lower prices on commodities. Japan and the East-Asia did also contract their import volumes and slowing trade down. (UN, 1999)

The US and Japan are the two countries that export the most to the non-OECD countries and these are, according to the study made by Coe et al. (1997) important countries when it comes to their domestic expenditures on R&D and their subsequent technological spillovers through trade. These two countries do show a positive trend in their export in the last years surveyed but some of the other big exporting OECD countries like Germany, France and Korea do not reach the same level of exportation as they had before the decrease.

Looking at the data, it gives the impression of that the possibilities for R&D to spread from the technologically advanced OECD countries to other countries was greater in the middle of the 11 year period than it was later on but, however, the trend seems to go slightly towards an increasing possibility for technological spillovers through trade.

One thing that might be interesting to single out when it comes to the total amount of trade between OECD countries and other countries is the trade between the first group mentioned and lesser developed countries. Using data from the OECD STAN database it permits a small selection of developing countries that are singled out from a larger group. When concentrating on countries classified by the World Bank (2006) as low or lower middle income countries one is able to find data regarding six countries, namely Brazil, China, India, Indonesia, Philippines and Thailand. It might therefore be interesting to see how exports from the OECD countries to these six countries has changed over the 11 year period and to see how these developing countries has gained from this trade regarding the theories concerning R&D spillovers. Here below is a summary of the total export to the six developing countries presented as well as the percentage of the total sum of export to all the non-OECD countries to this specific country since it might give a good picture of how things have changed over the years. The whole table is to be found in table 1B in the appendix. The years shown are the first and the last years of the time period.[12] [13] All of the numbers are still presented in thousands of PPP adjusted dollars given in the constant price level of year 2000.

Total export to low and lower middle income countries

Developing Countries

	Brazil		**China**		**India**		**Indonesia**		**Philippines**		**Thailand**	
	1990	**2000**	**1990**	**2000**	**1990**	**2000**	**1990**	**2000**	**1990**	**2000**	**1990**	**2000**
OECD in total	15230594	33913427	25767020	76395706	16409690	19495480	14692017	16375231	8850817	24319357	21431405	27823354
% of total export to the non-OECD countries	2,78%	3,83%	4,71%	8,63%	3,00%	2,20%	2,68%	1,85%	1,62%	2,75%	3,91%	3,14%

Source: OECD STAN Structural Analysis Database

When looking at the amount of trade presented above, it is easy to distinguish that China is the country that has received the highest amount of exports from all the OECD countries in both 1990 and 2000, also when it comes to the percentage of the total export. It is also the country with has had the highest increase in received exports from 1990 to 2000, closely followed by the Philippines. This is concurring with the resent expansion of the Chinese economy which has made it more interesting to trade with this country. Two countries that have increased their exports to China the most are two of the biggest exporting countries in total, namely the United States and Japan. The US has increased their export with little over two and a half times as much while Japan has increased their exports to China with over four and a half times as much as in 1990. Brazil and the Philippines are also countries that have largely increased their share of most of the OECD exports over this 11 year period. The other three countries, India, Indonesia and Thailand have also increased their shares but in a more modest way. When it comes to their share of the total amount of export to non-OECD countries one can even see that this share has diminished for these countries, if only slightly for Thailand. That export has increased largely for some of the six developing countries is a

[12] Luxembourg is still excluded from the table, so is also Austria and Korea this time due to lack of data in the beginning of the 1990th.

[13] The rest of the years of the time period are excluded due to lack of space, what is important is the overall change over the period

good sign that points towards an increased possibility for these specific developing countries to get access to the R&D developed in the OECD countries. The amount of trade has increased for the greater part of the countries, but for some the share of the total amount has diminished which might indicate that the technological transfer might decrease as well.

The countries that export the most of the OECD countries included are the United States, Japan and Germany. These are the same countries as mentioned in the study by Coe et al. (1997) where they distinguish which countries that are most important when it comes to a change in their domestic expenditure on R&D (Coe et al., 1997, p. 147). In the table one can also see that the US tend to export more to the countries that are closer to is geographically, like Brazil, while Japan tend to export to countries closer to it, like China and the South- East Asian countries. This is also mentioned by Coe et al. (1997, p. 148). However, the US has a large export to China as well. Germany does export quite equally to all the six countries in the table with the exception of China who does get a larger part of the export share. As geography might be an important factor in the decision of the world's trade directions and being closer to a large, highly developed country might be advantageous to a developing country when it comes to possible technological spillovers through trade.

4.2 Composition of Trade

The composition of the trade conducted between countries is much likely to matter when it comes to technological spillovers. For example, imports of high technology equipment do most likely contain more R&D than imports of food or oil. When looking at, for example, the study conducted by Mayer (2000) instead of using the total amount of trade, he breaks it down and examines how machinery imports to different sections of the economy influence the technological spillovers and the growth of a country. It might therefore be interesting to divide the total trade between the developed and the developing countries into smaller groups and to study trade in the types of goods that are most likely to contain a large amount of technology and how this has changed over the time period in question. Following the example of Mayer (2000) it might be interesting to compare how the exports in machinery and equipment differ from the total amount of export from the different OECD countries.

In the table in Appendix 1B the exports in machinery and equipment from the OECD countries to the non-OECD countries are presented[14]. The same condition as before is valid given the presentation of the amounts; they are in thousands of PPP adjusted dollars in the constant price level of year 2000.

When comparing with the table presenting the total amount of trade from the countries above, one can distinguish the same reduction in export from most of the countries presented during the last years of the 1990. The possible reason for this is described above when discussing the total trade. This is also here followed by an increase in the year 2000 but it does not reach the same level as, for example, in 1997 for all countries. However the increasing tendency is clear while looking at the total amount of export and it is a positive sign for the future. Another thing that concurs with the earlier presented data is that it is again the US and Japan that clearly provide the largest part of the world's exports of machinery and equipment. This time it is however Japan that exports for a larger amount that the US and does therefore have a higher share of exports that might provide technological spillovers.

What might be important to study is the share of the total exports from the OECD countries to the non- OECD countries that consist of export of machinery and equipment and how this has changed over the 11 year period since this sector is believed to contain a large amount of technology. Below follows a table that presents the percentages of exports in machinery and equipment for the year 1990 and 2000 respectively from 21 of the OECD countries to the non-OECD countries of the world. Beside Luxembourg, Austria and Korea are unfortunately excluded from the table due to lack of data for the year 1990.

[14] Luxembourg is again excluded due to lack of satisfying data

Percentages of exports in machinery and equipment to the non- OECD countries

Country	1990	2000
Australia	6,8%	6,9%
Belgium	13,7%	17,0%
Canada	12,2%	18,1%
Denmark	30,4%	33,7%
Finland	34,9%	59,4%
France	28,8%	34,2%
Germany	42,1%	43,1%
Greece	5,8%	14,9%
Iceland	3,1%	10,5%
Ireland	20,2%	57,4%
Italy	39,6%	36,7%
Japan	44,7%	52,1%
Netherlands	19,5%	36,4%
New Zealand	3,2%	6,0%
Norway	12,8%	26,0%
Portugal	16,5%	25,9%
Spain	18,1%	20,6%
Sweden	38,1%	59,4%
Switzerland	49,6%	47,4%
United Kingdom	34,3%	38,6%
United States	33,1%	48,6%

Source: Author's own calculations using data from OECD STAN Structural Analysis Database

As can be seen in the table, there are large differences between some of the countries regarding the share of exports of machinery and equipment. What is positive from the aspect of growth theory is that the share of export of machinery and equipment has increased in the greater part of the countries in question from the year 1990 to the year 2000. The countries that have the highest share of export of machinery and equipment in the year 2000 are Sweden and Finland. Almost 60% of their exports are of machinery and equipment. When looking at the two countries that provides the most export to the non-OECD countries, the US and Japan, they too have a large share of export of machinery and equipment, 48,6% and 52,1% respectively. This means that there is a great chance that there can be positive technological spillovers from these countries to their trading partners and the countries that trade with the OECD countries with the largest share of export in sectors containing much technology, like machinery and equipment, might gain the most.

Finally it might be interesting to investigate how much exports in machinery and equipment that reaches the low and lower middle income countries. Using the OECD STAN database, the data existing for those types of countries are the same as in the tables for total trade, namely Brazil, China, India, Indonesia, Philippines and Thailand. Below is a similar table presented as the one for the total amount of trade, only this time it is the exports made in the sector of machinery and equipment. The whole, country specific table is to be found in appendix 2B. At the bottom of the table are again each countries share of the total export in machinery and equipment to the non-OECD countries offered. The numbers are presented in thousands of PPP adjusted dollars given in the constant price level of year 2000.

Total export to low and lower middle income countries in machinery and equipment

Developing countries

	Brazil		China		India		Indonesia		Philippines		Thailand	
	1990	2000	1990	2000	1990	2000	1990	2000	1990	2000	1990	2000
OECD in Total	6024870	15243982	9795411	35176543	5077134	6229711	5547229	6012868	2890594	15984645	8690604	13696113
% of total export to non-OECD countries	3,21%	4,16%	5,22%	9,59%	2,71%	1,70%	2,96%	1,64%	1,54%	4,36%	4,64%	3,73%

Source: OECD STAN Structural Analysis Database

The tables, above and in the appendix, are quite similar to the earlier presented tables over the total amount of exports. Again, China receives the larges amount of export but it is the Philippines that have the far largest increase in receiving exports in the machinery and equipment sector. Also these countries shares of the total amount of export to the non-OECD countries have remarkably increased. The amount of exports of machinery and equipment has, to greater parts, increased from all the developing countries trading partners with a few exceptions. Indonesia has received less exports in 2000 that in 1990 from some of the European countries, e.g. Denmark, France and Portugal. Also Canada has marginally decreased their export to four of the six countries, namely China, India, Indonesia and Thailand. When looking at the percentages one can again see that they have diminished for the same three counties as mentioned above. The conclusion is that the amount of export has increased while their share of the exports towards all the non-OECD countries has diminished which might give those specific countries a slight disadvantage along the other non- OECD countries when it comes to possible technology diffusion.

As before, Japan directs its exports mostly towards Asia where Thailand and China receives the largest shares while the European countries tend to export quite evenly between the six developing countries. USA direct their largest export in machinery and equipment towards the country closest to them, namely Brazil, but China does also obtain a large part. It is a positive sign for all the six developing countries that the over all picture shows that the exports in machinery and equipment are increasing, but it might as mentioned be a disadvantage regarding the smaller share of total export to three of the six countries.

4.3 Available R&D Stock and technology diffusion, three different measures

4.3.1 R&D Expenditures in the OECD countries

Since the main part of the R&D expenditure and the largest part of the world R&D stock exist in the developed countries and that this might affect developing countries through trade, it is of interest to see how large the R&D stocks in the developed countries included in this thesis are and how it has changed over the years. How to measure the R&D stocks existing in the different countries is not that easy though. One way to do it is to sum up the expenditures made on R&D in a country for a number of years and take the depreciation of each year into account. When using the OECD database over the R&D expenditures made by the OECD countries, one discovers that there is not any data prior to the year 1987. Therefore the measurement of the R&D stock in this thesis will comprise of the sum of the expenditures a country has made on R&D three years back in time plus the year in question. The R&D stock will then include four years of expenditure on R&D.[15]

In the study performed by Coe et al. (1997) they examined how changes in the R&D expenditures of the developed countries affected their developing country trade partners. (see page 15) According to this study, changes in the R&D expenditures had quite a large effect and it is therefore interesting to include a survey of these in this thesis to see if the spending on R&D has increased over the 11 year period in question. If it has, there is a great chance

[15] For a small part of the countries there is some lack of data for a few single years and to be able to include these in the study I have been forced to assume that the R&D expenditures for these years were the same as the year after. The countries concerned are Belgium, Germany, Italy and Korea.

that the developing world has gained access to a larger part of the R&D stock of the developed world.

A table that shows the total R&D expenditures for the 17 countries included in this section[16] are presented in appendix 3. Unfortunately there is some lack of data regarding some countries in the selection, but the main tendencies are possible to distinguish. The results are quite varied among the different countries. The over all impression is that there is a slight increase in the expenditures on R&D for most of the countries. However, Italy, Spain and the United Kingdom do spend most on R&D in the first year of available data in the table. If one compares this data to the one regarding export from the OECD countries during this period, it is not possible to see the same dip in the end of the time period when it comes to R&D expenditures. It does exist for some countries but it is more common to see a downfall earlier in the time period, around the years 1993-1995. As already mentioned, the results for the different countries vary a lot.

Not surprisingly it is the largest countries that spend the most on R&D. The US is by far the leading country; they spend twice as much in the year 2000 as the Japan, the country that spends the second most. This has most likely to do with the large size of the country and its economy, as with its high level of development. The country that spends the third most is Germany, followed by France. Following the study made by Coe et al. (1997) mentioned above, one might, given their results, come to the conclusion that trade with the US is most profitable and that an increase in their spending on R&D will benefit the developing trading partners the most. Second best would be Japan, followed by Germany. Usually it is the countries that are the closest to these countries that trade the most with them. If trade were to be unrestricted, it is most likely the countries closest to the US that benefits most from the worlds technological spillovers.

It might also be interesting to look at the rate of R&D expenditures in the machinery and equipment sector in relation to the total expenditure on R&D since this sector is one that contains a lot of R&D as well as a sector much imported. The calculations are made for the first and the last year of the time period to see how it has changed from the beginning of the period to the end.

[16] The rest of the OECD countries are left out due to an unfortunate lack of data

Rate of expenditures on machinery and equipment

Country	Year 1990	2000
Australia	47%	54%
Belgium	40%	39%
Canada	67%	77%
Denmark	48%	42%
Finland	51%	77%
France	70%	64%
Germany	76%	74%
Ireland	56%	68%
Italy	72%	73%
Japan	66%	70%
Korea	78%	82%
Netherlands	51%	59%
Norway	53%	59%
Spain	65%	57%
Sweden	71%	71%
United Kingdom	58%	53%
United States	75%	74%

Source: OECD STAN Structural Analysis Database

The table shows somewhat diverse results. Some countries have raised their share of expenditures on R&D in the machinery and equipment sector while others have diminished theirs. If one looks at the countries that spends the most in total and therefore are important trading partners as concluded earlier, Germany, Japan and the US place a large share of their expenditures on R&D in the machinery and equipment sector. Their expenditures have been quite unchanged between the years 1990 and 2000 but Japan has increased their share a little. These three countries are also amongst those who place the largest share of their R&D expenditure on machinery and equipment. One other country stands out in this table and that is Korea. They had the largest percentage in both 1990 and 2000. This shows that Korea uses much of their expenditures on R&D in a sector that is likely to contain a large amount of technology which might be possible for other countries to enjoy thought trade and other international contacts. From an economic growth point of view, this is positive, not only for Korea is self but for the countries that engage in trade with this country.

4.3.2 Different measures of possible technology diffusion

The way to measure technology diffusion might differ from one researcher to another. One clear example shown in this thesis is the difference between the method used by Coe et al. and the one Keller puts forward in his study. Where Coe et al. uses the weighted imports from the countries exporting the R&D multiplied by the R&D stock of these counties, Keller creates his own imports weights (randomly chosen trade patterns) to multiply the R&D stock with.

It is now interesting to look at some measures of the possible technological diffusion between the OECD countries and the six developing countries brought forward in this thesis and see if there might be differences in the tendencies given the method used.

The first method used is one that starts out from the theory presented by Mayer (2000). In his study of technology transfer to developing countries he argues that it is not the intensity of the interaction between the countries that matters, but it is the contact in itself. (Mayer, 2000, p, 8). One can also see the same structure in the study made by Keller (1998) where he argues that the import structure for technological diffusion is of minor importance and where he constructs his randomly chosen trade patterns to prove this. Using this two studies as a starting point, one way of measuring the possible technological spillovers to the developing countries in this study is to assume that if a country is trading with another (in this case an OECD country), the country might be able to count the R&D stock of the developed country as its own as long as there is any trade at all going on between the countries. The trade considered is the trade in machinery and equipment which is a trade category that is likely to contain a large portion of R&D and taking into account that all types of trade may not give access to the R&D stock of the exporting country. When looking at the trade in machinery and equipment between 17 of the 24 OECD countries[17] one discovers that all of the six developing countries are engaged in trade with all of the OECD countries during the time period 1990 to 2000. Therefore they should also have access to and R&D stock of the same size. Here below is the summary of the 17 OECD countries R&D stock combined which is the R&D stock the six developing countries have access to. The table showing each country separately is to be found in appendix 4. The R&D stock for the different countries are calculated as mentioned earlier, by summing up the latest three years of R&D expenditures

[17] Seven of the OECD countries are unfortunately excluded due to lack of data

plus the year in question. The amounts are, as before, presented in thousands of PPP adjusted dollars at the constant price level of year 2000.

R&D Stock for the OECD countries

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
OECD in total	778454	770260	754865	728731	704070	699442	714951	751793	782861	806418	831353

Source: OECD STAN Structural Analysis Database

Looking at the amounts from a growth theory point of view, the increase in the total R&D stock in the last years of the time period is highly positive for the possibility of growth in the developing countries trading with these OECD countries. As all the six developing countries included in this thesis, Brazil, China, India, Indonesia, Philippines and Thailand, trade with all of the OECD countries included, they are able to count the R&D stocks presented above as theirs. There is a slight decrease in the R&D stocks around the years 1994-1996. This can have a probable explanation when looking at the R&D expenditures presented above where one can see a similar decrease around these years, something that quite possible will have an effect on the R&D stocks since the measure for it used in this thesis in based on those.

Another possible measure that one can use when calculating the technological transfer is one that spring from the two studies made by Coe et al. (1995, 1997). It is a measure where one uses the imports of machinery and equipment as a weight of the R&D stock available for the recipient countries. The technique is to multiply the R&D stock of one country with the share of the total import of machinery and equipment from that country and then do the same for each of the countries trading with the one in question and finally sum up all the amounts to see the possible technological diffusion to this country.

The table below shows the data which is of highest interest for this thesis, namely the total sum of the R&D stock that is becoming available for the six developing countries using the measurement presented above. There are still only 17 OECD countries included in the measure due to lack of data on R&D expenditures. The numbers are ones again presented in thousands of PPP adjusted dollars at the constant price level of the year 2000.

Sum of available R&D Stock through trade in Machinery and Equipment

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Brazil	174564	178289	178026	163705	166246	164741	169855	191734	194502	202176	221178
China	114142	122301	124670	119551	110909	110631	114937	127741	137696	140910	147068
India	128492	117032	116298	126567	109882	105198	107047	125295	126720	133952	144218
Indonesia	111235	118484	126419	109373	114674	109912	109452	121339	132940	135813	147297
Philippines	178930	176989	167557	160354	164468	168701	164495	185877	202003	207306	211393
Thailand	133001	139117	141235	136529	135946	132181	134561	154744	176493	185221	197114

Source: OECD STAN Structural Analysis Database

The results from this type of measurement might seem a little odd because the table shows that China is one of the countries that have one of the smallest available R&D stock even though it was the country receiving exports of machinery and equipment. The explanation for this is that their exports received have its origin in many of the OECD countries and that the share of exports from R&D rich countries like the US and Japan becomes smaller. Therefore their total sum of available R&D stock is lesser since a larger part of their exports derives from countries with a smaller domestic R&D stock compared to some of the other developing countries accounted for in this thesis. However, contact through trade with a large number of countries might give access to a large diversity of technology which might be positive for the technology acquisition. Given the results above, Brazil is the country that is exposed to the highest R&D stock coming from the OECD countries. The explanation for this is the large share of exports in machinery and equipment that comes from the US, the country that has the highest R&D stock of the OECD countries taken into account. The country that has access to the second largest R&D stock is the Philippines. One reason for this is the large shares of exports that come from the R&D rich countries, Japan and the US. The slightly lower R&D stock available to the other developing countries might have its explanation in that their trade is more diverse and that they their shares of exports received is higher for a larger number of countries, some with a smaller domestic R&D stock. This makes the R&D stock available and the possible technological spillovers smaller with this type of measurement.

What is positive for all the six developing countries is that the possible technological diffusion is at its highest in the year 2000 and has been increasing for most of the last years in the 11 year period. There is a decrease of the amounts in the middle of the period, similar to the one concerning the OECD countries different expenditures on R&D which also is the reasonable explanation for this decrease. However, the dip in the trade with machinery and equipment that is shown in the table above is not able to detect with this measurement since the shares of trade might be constant even though that the total amount might decrease.

The third and last measure for the technological spillovers that will be presented in this thesis is one where the intensity of the trade in R&D intensive goods, in this case the trade in machinery and equipment, is of importance when looking at the possible technological transfer of the R&D stock from the OECD countries. This can be traced back to the study made by Schiff et al. (2004) were they conclude that openness to trade is more important than the actual content of the trade when it comes to developing countries. The thought is that one unit of imports contain the same unit of R&D, no matter where this import comes from as long as it is one of the OECD countries. Since the unit of the R&D stock that transfer through trade not is important, the easiest way is to assume that one dollar of imports of R&D intensive goods corresponds to one dollar of R&D stock. To give an example of this measure one can therefore look at the trade that has taken place between the OECD countries and the six developing countries, just as has been done above when presenting the table over trade in machinery and equipment. That table shows the change in trade in this type of goods between the year 1990 and the year 2000. Here below is a table presented that shows the total amount of exports in machinery and equipment received by the six developing countries regardless of which OECD country it derives from. This table is similar to the table 1B in appendix but it facilitates the comparison against the other measures of the technological spillovers. There are also only 17 of the OECD countries that are included in the table for the sake of using the same countries as in the previous measures. The amounts are presented in thousands of PPP adjusted dollars given the constant price level of the year 2000.

Total amount of export of machinery and equipment from the OECD countries

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Brazil	3804527	3976624	4215016	5316408	7126544	10926641	12874609	16137689	15343856	13744901	15846518
China	6766391	8084452	11267373	18140758	21291148	26441643	27700181	26525355	26731975	30289079	40089479
India	3048867	2875047	3081235	3438527	4442587	7212160	7399393	6542601	6524840	5739887	6406086
Indonesia	4096055	5214054	6035173	6054497	6859584	9784757	10805738	12077776	5356000	4445275	6816745
Philippines	2526553	2692808	3692485	5068699	6311591	8520126	11426680	14080420	13138264	14789915	17948543
Thailand	6305708	7570636	7985311	9853457	12589125	17586555	17596085	15856954	10204724	10680602	14453275

Source: OECD STAN Structural Analysis Database

Contrary to the other two measures, this one does not show the same decrease in the middle of the time period. Instead, this decrease comes a few years later, around 1997-1998, just as one was able to see in the trade data presented earlier in this chapter. Therefore this last measure shows a slightly different picture when it comes to the possible technological spillovers. The reason for the decrease in trade might be, as mentioned before, the increased risks in the trade market and the lower price of commodities during these years (UN, 1999). There is however an increase in trade in the last years of the time period which indicates that there might be a greater chance for R&D to spread to these developing countries. One can also see that there has been a great increase from the beginning of the period to the last year presented. The far largest increase has been in China where the trade has increased with almost six times the amount of trade in the year from the year 1990 to the year 2000. Other countries that also have had a large increase in exports received are Brazil, the Philippines and Thailand. India and Indonesia are countries were the increase has been more modest.

The numbers are also quite a lot higher that when using the other measurements because one now uses the total amount of trade and do not weight it against either the R&D expenditures or the trade shares.

All the three measures on technological spillovers presented above are quite broad and rough ones and it is difficult to say with one that shows the best picture over the possible technological diffusion to the developing countries. It is not really relevant to look at the actual amount of the three measures since they take different factors into account. The interesting thing to survey is if the different measures points towards the same direction when it comes to possible technological spillovers or if they show a diverse picture.

The measures presented can all be connected to other empirical studies made in this area and it shows that there are a lot of different possibilities when it comes to estimate the possible technology diffusion that is desired from a growth perspective. All measures above include either the R&D expenditures of the OECD countries, the trade in R&D intensive goods or both. When looking at the results all measures point towards an increase in the possible technological transfer but there has been some varied results during the period. However, the data over the last years is positive for growth. The largest increase has been in the measurement that uses trade in machinery and equipment as a measure of the possible technological transfer that take place. The other measures do not show the same amount of increase but does give a positive indication of technological spillovers.

4.4 Education

Education is one factor that is of much importance when it comes to growth and also to the acquisition of possible technological transfer. As seen in the earlier described theory, the technology diffusion theory by Jones (Jones, 2002, p.124ff.) human capital plays a major role for growth of the economy and human capital is much acquired through education. It is also important when looking at the theories regarding trade and growth, put forward by Grossman and Helpman (1991), where they reason that a country which has a great deal of unskilled human capital might, when engaging in trade, specialise in traditional manufacturing and not take the opportunity to grow despite the greater access to world technology. For that reason it might be interesting to see how education in the six low and lower middle income countries included in the OECD STAN database has changed over the 11 year period that is being studied. Statistics for education is gathered from the educational database created by Robert J. Barro and Jong-Wha Lee (2000) and is unfortunately only given for every fifth year but one is able to see how it has changed from 1990 to 1995 and from 1995 to the year 2000.

To see how the education has changed, a good measure might be the average years of schooling in the different countries.[18] This is measured, as mentioned before, every fifth year in the Barro- Lee database (2000) and the results for the six developing countries are presented in the table here below.

Average years of schooling

	1990	**1995**	**2000**
Brazil	4,02	4,45	4,88
China	5,85	6,11	6,35
India	4,10	4,52	5,06
Indonesia	4,01	4,55	4,99
Philippines	7,28	7,88	8,21
Thailand	5,58	6,08	6,50

Source: Barro-Lee (2000)

[18] It is important to acknowledge that one can choose other types of measurements for human capital but years of secondary schooling is often used in different studies in this field and gives a good appreciation of the skill level of the human capital.

As one could expect, the average years of schooling have risen in all the countries included. There are however differences both in the number of years of schooling and how much it has increased over the 11 year period. The number of years of schooling is the highest in the Philippines with in average over 8 years of schooling in the year 2000. Thailand and China follows the Philippines with each close to 6,5 years of schooling in the year 2000. The country with the least amount of years of schooling in the year 2000 is Brazil. When looking at how much the countries has increased their average rate of years of schooling over the years studied, most of the countries have added almost one year to the average years of schooling among its inhabitants. Indonesia is the country that has increased the most with 0,98 years of further schooling, closely followed by India where the time has gone up with 0,96 years. China is the one country that stands out in this group. Over the 11 year period, the average years of schooling in China has only gone up with 0,5 years.

When looking at the results above one can draw the conclusion that, from the growth theories, the Philippines have the best requisites to grow economically by taking advantage of the technology frontier given by trade. Also Indonesia has a good chance if the growing average years of schooling continue, preferably at an even higher rate.

4.5 GDP Levels

Finally it might be of interest to look at the six developing countries' GDP levels per capita to see if it follows the positive indication of possible technological spillovers which facilitates growth. Of course there is a lot of other factors affection the countries' GDP levels but however it might be important to see if they point at the same direction. Here below is a table included that shows the different developing countries GDP level per capita at the years of the survey. The data is gathered from the data collection Penn World Tables Version 6.1 (Aten et al. 2002) and are shown in constant price: chain series.

GDP Levels per capita for the Developing Countries

Years	Brazil	China	India	Indonesia	Philippines	Thailand
1990	6218	1787	1675	2851	3009	4833
1991	6220	1975	1664	3031	2948	5166
1992	6072	2203	1707	3196	2887	5477
1993	6294	2455	1775	3339	2885	5832
1994	6575	2645	1863	3506	2951	6288
1995	6765	2818	1979	3645	3029	6765
1996	6881	2969	2118	3891	3122	7094
1997	7014	3110	2162	3990	3358	7029
1998	6732	3276	2287	3528	3221	6274
1999	6889	3415	2414	3529	3335	6514
2000	7190	3747	2479	3642	3425	6857

Source: Penn World Tables Version 6:1

When looking at the amounts presented one can see that they have all increased over the time period studied. One can also detect a downfall in the numbers during the years 1998-1999 for all countries except China and India, something that is concurring with the downfall in trade during this period. This might be a sign that these specific developing countries are at least sensitive to the impact of trade with other countries and given the theories concerning technological spillovers through trade, this might effect growth in that country. The countries which have had the largest increase in GDP levels are China and Thailand, something that is concurring with the increase of export to these countries from the OECD countries, even though the share of the total amount of OECD export to non-OECD countries has gone down slightly for Thailand. This might indicate that there are a lot of other factors in a country that also affects the GDP level, but by and large one can detect a similar pattern in the GDP levels as in the data concerning trade and possible technology diffusion presented above.

5 Conclusions

This section will sum up the different parts presented so far and tie the theories, earlier empirical research and the resent data on trade and R&D together to create a complete picture over the possibilities for developing countries to gain technology from trade with developed countries. Conclusions will be drawn and generalised to be of use to further research. Finally some suggestions for further research will be presented.

Technology is an important building block for economic growth. This has been elaborated in several economic growth theories. It is possible to affect the technology to produce higher growth. One way of doing this is to engage in domestic research and development and in that way create technology. This is however not always a possibility and another way of obtaining technology is to engage in trade to take part in the world's technology resource. This is often the best alternative for less developed countries where the domestic resources are not enough to support a large research and development sector. As seen by the earlier presented theories, to be able to benefit from the world technology there is a few factors that facilitated this. A country needs to engage in trade. Earlier empirical researchers have proved that the more a country opens up for trade, the more technology spillovers it can obtain. Another important factor is that a country has the human resources to be able to make use of the possible technological spillovers. For a developing country engaged in trade, the amount of technology existing in its trading partners, usually measured by the spending on research and development, does also affect the possibilities to grow.

When looking at recent data over the amount of trade coming from the highly technologically advanced OECD countries to the non-OECD countries, one can see that over the 11 year period studied there has been an increase. This indicates that there are possibilities for technology to diffuse to the rest of the world. This theory is reinforced by the fact that there has been an increase in the trade of machinery and equipment, a sector that is much likely to contain a large amount of technology. It is however at bit concerning that trade diminished in the years 1998-1999 and sunk to quite low levels. The trend does however show that trade went back up in the year 2000, even though it did not reach the same levels as in 1997 for all the OECD countries. By and large, the increasing amount of trade from the OECD countries to the non-OECD countries is positive when it comes to possible technological spillovers.

Turning to the data on the different OECD countries expenditures on research and development, the results shown are a bit diverse. There is not possible to see a great increase in the spending and for a few countries there has even been a decrease since the beginning of the period. For most of the countries it is however possible to see a slight increase in the spending and this is seen as a positive sign regarding the possibility for technological spillovers. Following the study made by Coe et al. (1997), an increased amount if expenditures on R&D in a developing country give higher spillovers to a country trading with that one. When looking at the expenditures on R&D in the machinery and equipment sector, this shows a similar picture. Some of the countries have increased their share of spending in this sector while a few slightly have decreased it. However, the expenditures have not increased a great deal and while looking at the rate of expenditures on the machinery and equipment sector compared to the total expenditures, the rate has not always gone up over the period studied. The rate is luckily quite high for most of the countries, but it has gone down in the year 2000 for important trading countries as for example the USA and Germany. The high rate does nevertheless promote a great opportunity for the countries trading with these countries to take part of the technology created by them.

Looking at the six developing countries singled out in this thesis, one can discover that when it comes to the amount of exports received from the different OECD countries, it has, with a few exceptions, increased for all countries. This is both when it comes to the total trade and trade in machinery and equipment. However there has been a decline in some countries share of the total amount of export to non-OECD countries, something that might not be to an advantage for these developing countries in particular alongside other non-OECD countries. Nevertheless, according to earlier empirical research, e.g. Schiff et al. (2004), the increase in openness it positive for the possibility of technological spillovers, especially the increase of trade in the machinery and equipment sector because that type of trade is expected to contain a large amount of technology. Again the high rate of expenditures on research and development on this sector should be mentioned as positive for the developing countries.

When it comes to the ways of measuring the R&D stock and the possible technological spillovers which the developing countries might get access to trough trade, three different measures are presented in this thesis. The amount of possible technological spillovers differ, quite expectedly, between the measures but they all point towards the same direction, that there has been an increase in the data that might facilitate for technology to transfer from the OECD countries to the six developing countries included in the thesis regardless of which measure one looks at.

Human capital has also been mentioned as an important factor when it comes to the attainment of and the growth from technology. Used in this thesis as a measure of human capital in the six developing countries are the average years of schooling. The data shows some different results. The highest number of years of schooling is found in the Philippines with over 8 years in average while the lowers number is found in Brazil with almost only half of that, 4,88 years in average in the year 2000. All countries have however increased the amount of years in average spent in education during the 11 year period and that is a positive sign for growth. Unfortunately, none of the countries has increased the amount of average years of schooling with even a year over this period. Indonesia comes closest with an increase of 0,98 years while China only has increased their amount with half a year. To be able to benefit from the increasing trade and the high rate of R&D in the developed trading partners, the developing countries should have an equivalent increasing rate of human capital and this might be where it sometimes fails when it comes to economic growth.

Returning to the initially posed questions it seems as if the non-OECD and the selected developing countries have gained when it comes to economic growth from technological spillovers during the 11 year period between 1990 and 2000. Most of the data points in this direction. Trade has gone up, both in total and in the technology rich machinery and equipment sector. Expenditures on research and development have increased and for the greater part of the OECD countries the rate of expenditures on the machinery and equipment sector has gone up. Looking at the R&D stocks, all three measures shows that there has been an increase in the end of the time period studied, though there was a decrease in some years the middle of the period for all measures. The last year in the period does however points towards a larger R&D stock available and this is a positive sign for the possible technological transfer. Finally the average years of schooling for the chosen developing countries has increased. Combining these results with economic growth theory concerning technology, all the indicators point towards a gain for the non-OECD countries during this period.

Finally while looking at the GDP levels per capita for the six developing countries singled out in this thesis, one is able to see a similar increase as the one shown in exports from the OECD countries and in the measures for technological spillovers. While a country's GDP level is affected by a large number of different factors, it is however positive to see that it has grown and that this might be to some part an effect of technological transfer from trading with the OECD countries.

Continuing on this subject it might be interesting for further research to look at the effect of other possible ways of technology to spread over the country boundaries, such as foreign direct investment or the impact of engagement in international science seminars if possible. Other measures on human capital might as well be added to the study field. It could also be interesting to do a follow up of what happened with the data after the year 2000, if the positive trends for economic growth though technological spillovers were kept up.

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Appendix 1A

Total export to non-OECD countries

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Australia	15301917,3	15979081,2	17109778,7	17202481	19469106,4	22154252,5	26014558,3	27765344,2	21836914,2	22213415,5	25883319,5
Austria						8564311,91	8316856,56	8741952,75	8139010,8	7865878,12	8124899,32
Belgium	15754385,1	16075685,5	16680508	17387567,9	18463503,8	22013268,2	21478478,6	23417997,3	20425128,8	20331699,9	22037928,2
Canada	11205121,4	11903951,6	10957228,3	8964186,15	9939839,87	13139401,1	12894752,8	14832225	11392653,4	10361129,5	11715880,1
Denmark	5066684,9	4491543,4	5526449	4602741,29	5504804,36	6925201,77	6722637,69	6462627,83	6166036,6	5350152,82	5467634,68
Finland	7643958,15	4530557,57	4091433,79	5311268,3	6866303,14	9982930,41	10621607,2	11220263,9	10700543,4	8819225,56	10532914,4
France	46036673,4	44852965,5	49839468,8	48577817,1	48661075,3	61054742,7	54054590,4	56087842,5	55275373	50312178,7	51240243,6
Germany	69363352,6	74915309,8	80099166,9	71476962,8	76696862,6	89828987,3	86887966	86728629,5	83698706,4	75263915	77527934,6
Greece	4399935,64	4108429,42	3919614,85	4267212,99	4257846,68	4288718,5	4793728,1	4358793,72	3801370,73	3581100,12	4341826,64
Iceland	169029,833	89926,7413	86404,4813	89714,5111	69419,0778	113417,54	176607,939	172861,827	115726,167	114347,517	115500,993
Ireland	1922487,64	1809902,19	2274971,86	2614067,83	3295435,44	4075197,17	5389047,86	5114775,8	5500282,43	6203797,47	6184656,75
Italy	47501244,4	46837290,5	50417704,1	51842598,6	52090850,2	61210618,2	66445040,4	60537865,8	54435233,3	45592686,8	47836373,7
Japan	107024285	123249190	140096304	153598911	167161568	194354967	181633973	185350799	156815653	164485997	198874871
Korea					90484513,8	118088901	118324176	111170008	93107865,2	90430360,4	99622549,8
Netherlands	13826098,8	12073168,1	13572426,6	17159182,3	15153388,4	19021378,8	17914945,4	17897736,4	16268741,9	15412400,6	16878178,4
New Zealand	2459676,76	2774487,26	2910642,36	3040375,6	3457872,08	3973446,26	4488243,2	4262601,11	3412966,01	3247053,64	3541107,84
Norway	3190369,81	3267706,05	3464263,38	2995068,91	2960789,37	3781505,49	4027468,18	4235812,83	3038667,17	3168912,15	3103832,96
Portugal	2360338,43	2134484,81	2676391,03	1889498,74	1984026,03	2393852,61	2560119,1	2365977,63	2127007,75	1705936,06	1940178,23
Spain	12593643,1	12574912,6	13802889,9	14310003,3	14280848,5	18132751,9	19567341,1	19812994,6	18902264,8	17889372	18362929,8
Sweden	8789062,19	8526779,29	7866821,06	8389428,64	9429227,51	11581154,6	13363119,1	13632352,7	12504127	10915421,6	12933872,4
Switzerland	13058683,3	11829589,6	12303732,3	12862921,3	13429109	15010643,5	15030091,4	14259191,2	12868656,8	12998825,5	13721976,9
United Kingdom	42428618,8	37801922,8	38664788,9	40308223,4	42212705	51731640,5	47390139,5	60303717,5	48436742,2	41766190,4	43042547
United States	117392867	136365415	149512116	155006602	162451953	188173585	195244328	213834788	199888441	182295990	201860828
Total export	547488434	576192299	625873104	641896833	768321048	929594874	923339816	952567159	848858112	800325986	884891984,8

Source: OECD STAN Structural Analysis Database

Appendix 1B

Total export to low and lower middle income countries

Developing Countries

	Brazil		China		India		Indonesia		Philippines		Thailand	
	1990	2000	1990	2000	1990	2000	1990	2000	1990	2000	1990	2000
OECD Countries												
Australia	93586	330242	1215711	3474215	603362	1059507	1274359	1672599	440207	881532	572224	1132480
Belgium	194086	793230	453550	1243302	1889690	3199171	285777	240487	105574	102248	625387	544415
Canada	511183	707648	1712363	2445884	319159	362308	323411	474797	211879	259773	512922	249460
Denmark	62767	194428	116572	404464	81262	126615	72595	49230	50518	53753	155648	138850
Finland	115553	316366	205398	1333301	146671	287234	65154	152159	44218	419799	143486	172636
France	869439	2129297	1673158	2972237	1199345	863932	616867	354770	259917	573369	906860	697115
Germany	2169285	4544617	2985435	8579782	2095849	1865148	1853237	1110687	744314	815206	1719201	1670345
Greece	7946	20432	95085	30661	18279	40965	16333	19643	8969	5091	35139	18374
Iceland	5098	450	437	11194	8	224	168	189	0	24	113	747
Ireland	37085	189414	10051	153095	17230	100889	12501	81069	23725	636049	38412	129747
Italy	1260133	2241416	1553441	2151104	875394	912194	555604	395269	246516	270851	669905	496046
Japan	1325566	2521960	6666024	30378789	1865277	2485821	5462090	7586651	2738745	10257737	9924402	13632370
Netherlands	295464	452407	287023	791601	451888	371970	498973	290238	117155	193609	219535	300323
New Zealand	15460	33706	105672	409128	78723	84920	111143	199301	97737	182253	95092	151818
Norway	107825	168696	135683	267950	30404	69094	14027	24221	13312	33040	80461	55607
Portugal	87802	181891	68794	48699	46046	23519	11761	1710	9249	6982	17820	22824
Spain	296771	1129026	474622	507445	178094	194718	180039	199006	46528	107156	197942	150980
Sweden	394906	679674	371147	1889127	421169	287349	207432	224527	56235	149571	381253	292681
Switzerland	413637	746935	340038	830158	324721	388058	262431	127659	141766	166344	476010	445663
United Kingdom	751999	1171980	1210183	2221137	2693691	3109054	470793	624212	390705	414804	1023088	878364
United States	6215001	15359612	6086635	16252433	3073428	3662790	2397321	2546807	3103550	8790166	3636504	6642509
OECD in total	15230594	33913427	25767020	76395706	16409690	19495480	14692017	16375231	8850817	24319357	21431405	27823354
% of total export to the non-OECD countries	2,78%	3,83%	4,71%	8,63%	3,00%	2,20%	2,68%	1,85%	1,62%	2,75%	3,91%	3,14%

Source: OECD STAN Structural Analysis Database

Appendix 2A

Total export to non-OECD countries in machinery and equipment

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Australia	1047223,942	1232360,275	1379449,364	1649068,789	2004304,022	2527778,12	2829236,781	2628509,903	2005657,808	1712581,434	1796809,967
Austria	-	-	-	-	-	2686519,277	2446282,23	2796514,423	2694948,834	2775721,922	3016047,386
Belgium	2150120,008	2111981,346	2115292,789	3110372,095	3292875,164	3580810,674	3384363,983	3737851,047	3463867,518	2916099,596	3752606,023
Canada	1371391,594	1281928,966	1527548,189	1927486,418	2055832,028	2276312,978	2531704,11	2822444,456	2185179,381	1843482,365	2116574,468
Denmark	1538225,074	1354862,754	1639901,266	1458386,061	1742534,591	2425262,208	2242464,084	2135663,144	1973716,257	1716996,565	1842303,556
Finland	2668889,86	1443455,883	1452231,032	2218823,084	2728105,227	4020123,224	4487648,736	4996176,662	5384919,693	4676469,02	6259055,627
France	13243096,88	12754631,59	13243459,94	13549697,21	14078841,3	17723433,71	17099524,06	18328887,77	18842167,05	17010037,35	17534567,63
Germany	29202418,59	31183989,49	33074119,21	30793134,95	33156443,55	39161633,94	39322485,81	37808779,24	36879926,64	32644444,87	33378851,12
Greece	254333,2391	208858,0199	274092,5278	320349,5139	317337,34	399424,768	384884,6093	424640,7778	409911,2524	416755,7637	645144,9472
Iceland	5176,253623	5290,691764	4227,316699	4860,689535	4531,571334	9147,671651	9822,92526	8266,664836	7790,902208	8306,239503	12142,99927
Ireland	389275,7846	389030,1273	470294,1438	687679,6851	975366,4342	1367281,254	2089564,837	2197283,29	2599622,52	3403587,253	3548828,859
Italy	18808770,29	19085837,43	19904023,17	21017883,52	20527215,05	23508084,67	26463362,75	23365443,48	20017238,92	17430641,32	17555695,33
Japan	47792864,21	56635495,3	63799530,29	70429692,48	80843304,87	96537985,28	90005377,08	89950129,13	74716428,86	81006157,69	103601945,7
Korea	-	-	-	-	20026788,9	26677997,54	27101249,94	26239831,72	22717747,23	26358499,39	31346295,5
Netherlands	2698431,033	2934153,263	3253271,399	4136168,985	3960453,262	4500336,84	4942898,453	5216368,904	5291932,368	5258964,187	6140306,786
New Zealand	79424,16918	115703,1801	142943,558	175224,5531	214111,2036	260514,0273	310231,8364	285096,3091	234985,9745	186217,829	213918,9299
Norway	409199,22	433968,8306	491527,8354	471863,8961	555118,3259	707018,0731	932371,5896	928986,9961	851203,9104	655073,0978	807084,7285
Portugal	388543,7862	367171,2348	432363,8297	291132,5931	334191,8554	475059,1017	537887,2216	530061,2248	533346,0397	403090,2643	502126,0591
Spain	2278920,644	2394868,232	2924437,249	3447123,675	3527679,88	4400417,387	4707209,857	4708107,765	4525202,644	3968367,352	3776963,749
Sweden	3345218,176	3240756,346	3019581,129	3279088,659	4291645,222	5554451,604	7178685,932	7690454,559	7293733,624	6407792,583	7677612,823
Switzerland	6472517,322	5752056,481	6291868,379	6352655,563	7007006,31	7789671,058	7547563,831	7043882,229	6349252,308	6230283,185	6499797,917
United Kingdom	14531881,47	12862594,76	13453180,22	13630502,09	15153809,31	17854909,47	17635795,28	20272937,7	18093918,63	15377000,51	16611932,95
United States	38820785,88	45985925,46	51044969,09	57455341,36	63992497,02	76943052,47	80997680,04	92933112	84282142,04	81583242,69	98164733,35
Total export	187496707	201774920	219938312	236406536	280789992	341387225	345188296	357049429	321354840	313989812	366801346

Source: OECD STAN Structural Analysis Database

Appendix 2B

Total export to low and lower middle income countries in machinery and equipment

Developing countries

	Brazil		China		India		Indonesia		Philippines		Thailand	
	1990	2000	1990	2000	1990	2000	1990	2000	1990	2000	1990	2000
OECD Countries												
Australia	5056	34916	39296	130103	18469	73200	122118	139252	15978	86300	53088	69906
Belgium	52245	194363	85502	308853	48560	93435	66519	43338	27478	34593	52746	87412
Canada	28125	95190	245475	233347	67387	50653	18133	15267	10786	55379	35225	28307
Denmark	23604	62262	81700	241069	52844	61575	46328	17557	15134	21836	110783	86635
Finland	30675	178134	110498	1132655	30585	208351	17954	124589	12682	375399	97889	130438
France	264542	627377	797991	1415544	302775	394451	347947	131591	94174	414245	278843	241239
Germany	1129980	2033922	1768735	4591356	1091451	1002678	1006465	457990	350147	504535	846670	804593
Greece	859	4186	32	1723	2948	3061	58	3490	18	267	2018	9695
Iceland	0	42	0	3291	0	15	0	29	0	0	20	188
Ireland	5849	99704	4405	88046	8849	66448	2845	10333	1488	536606	13804	52893
Italy	604933	1109694	1001852	1305534	398901	474760	365178	203019	68117	151913	410583	251375
Japan	926123	1419220	2639202	15101097	805697	1072781	2348216	3591305	956125	6735146	4300642	7162068
Netherlands	75593	144389	92072	287786	104405	120033	128605	76924	12018	90318	60524	112758
New Zealand	254	6982	1102	9414	998	3967	3388	3007	1023	3572	1490	3038
Norway	7461	34007	39251	98702	12066	17061	4070	4910	5104	22184	3189	3985
Portugal	9459	41854	2228	25247	16030	4929	1371	222	1707	3254	3611	1985
Spain	95986	268355	181437	204328	24047	34248	51038	59456	5851	13925	25156	57392
Sweden	173518	438770	289093	1540720	136319	191366	56496	125746	13956	89096	151307	149027
Switzerland	190661	253689	274109	554808	197916	231222	153855	61734	62997	95081	313638	288135
United Kingdom	225436	368540	612804	1205764	761986	582472	166305	159528	136119	219368	337647	259857
United States	1706179	7828386	1199402	6697156	780625	1543005	502427	783581	1099692	6531628	1248914	3895187
OECD in Total	6024870	15243982	9795411	35176543	5077134	6229711	5547229	6012868	2890594	15984645	8690604	13696113
% of total export to non-OECD countries	3,21%	4,16%	5,22%	9,59%	2,71%	1,70%	2,96%	1,64%	1,54%	4,36%	4,64%	3,73%

Source: OECD STAN Structural Analysis Database

Appendix 3

Total R&D expenditures

	Time Period										
Country	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Australia	1002	1128	1384	1393	1567	1935	1809	1727	1575	1559	1717
Belgium	-	-	2410	2456	2498	2513	2611	2773	2753	2930	3146
Canada	3410	3315	3323	3573	4015	4289	4368	4861	5479	5738	6915
Denmark	738	770	764	769	835	911	974	1033	1200	1247	-
Finland	1160	1097	1036	1039	1218	1390	1633	1824	2140	2374	2722
France	15969	16469	16467	16356	16359	16260	16523	16424	16499	17374	17961
Germany	30134	31467	29932	27671	26303	26319	26603	27207	28551	30611	33082
Ireland	273	311	387	479	563	612	663	686	695	678	631
Italy	-	9722	8790	7548	6960	6606	6656	6225	5548	5696	6068
Japan	51272	53087	50924	47534	47363	50961	54959	59564	60995	61572	66584
Korea	-	-	-	-	-	11331	11823	11712	9300	9735	11398
Netherlands	3210	2982	2875	2861	2979	3136	3151	3270	3173	3563	3658
Norway	565	546	553	563	-	594	633	620	572	590	703
Spain	3113	3015	2697	2398	2180	2236	2433	2391	2806	2822	2934
Sweden	3853	3676	3619	3614	4108	4481	4783	4760	4788	5244	6271
United Kingdom	17011	14805	13694	13602	13326	13104	13014	13352	13590	14362	14583
United States	113346	108681	106607	105240	106197	113768	125009	131885	128958	123925	129594

Source: OECD STAN Structural Analysis Database

Appendix 4

R&D Stock for the OECD countries

OECD countries	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Australia	2028	2071	2206	2347	2654	2972	3112	3301	3299	3221	3355
Belgium	3877	3764	3772	3823	3858	3948	3932	3925	3948	4037	4297
Canada	9041	9023	9014	9251	9765	10507	11305	12440	13785	15080	17327
Denmark	1352	1401	1438	1481	1529	1592	1681	1816	1954	2049	2114
Finland	2435	2411	2339	2254	2408	2776	3385	4139	4995	5899	6844
France	39979	42428	44505	45439	45467	44789	44160	43570	42893	43161	43858
Germany	93968	91922	89711	86441	82660	79544	77428	77079	78728	81922	86974
Ireland	489	547	630	747	877	1028	1212	1393	1560	1697	1756
Italy	33065	30943	28861	26381	23980	21785	20248	19442	18429	17909	17462
Japan	110043	122387	130060	131021	127735	127020	130997	141363	152722	161757	171812
Korea	57892	54561	50872	46899	43206	39662	37787	37213	35412	34453	34422
Netherlands	7081	6617	6096	5710	5589	5839	6195	6617	6851	7181	7656
Norway	1357	1274	1190	1155	1147	1173	1233	1284	1299	1309	1379
Spain	6425	7101	7373	7256	6559	5947	5587	5511	5790	6109	6361
Sweden	11150	10951	10763	10578	10763	11326	12139	12927	13363	13860	14915
United Kingdom	40282	38793	36246	33400	30591	29111	28678	28333	28522	29330	29977
United States	357987	344066	329788	314546	305283	310423	325872	351441	369310	377444	380845
OECD in total	**778454**	**770260**	**754865**	**728731**	**704070**	**699442**	**714951**	**751793**	**782861**	**806418**	**831353**

Source: OECD STAN Structural Analysis Database