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The effect of R&D expenditure on Productivity and Innovation

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THESIS ACCEPTANCE CERTIFICATE

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The effect of R&D expenditure on Productivity and Innovation

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Abstract

R&D expenditure is motivated by the desire to achieve economic growth. In previous research a positive relation between research and development and economic growth was found. When it comes to empirical research related to R&D and productivity growth we can distinguish three types of studies. First, country level studies related to the effect of R&D in countries economies. Second, industrial level studies related to the impact of R&D on certain industries, such as manufacturing or agriculture. Third, firm level studies related to R&D efforts and its impacts on the performance of companies and firms. This study focuses on the effect of R&D on country level using panel data analysis to find a correlation between total factor productivity and research and development expenditure. This paper includes data from developed and developing countries and includes income and regions dummies to check whether the performance in total factor productivity proves to be negative or positive depending on income level or regional characteristics.

Regarding the effect of R&D expenditure on innovation, this study focuses on Latin-America, it includes data from 1996 to 2011 and an input-output approach to determine if R&D expenditure leads to a higher degree of high-tech exports and patents creation and if it does, which sources of funds of R&D (government, higher education) are more significant.

Regarding R&D and productivity, results show there is a positive correlation between the growth of total factor productivity and R&D expenditure. Regarding R&D and innovation in Latin America, results show that government R&D expenditure has not been very effective in promoting high technology exports in Latin America, R&D in higher education institution proves to be more significant to increase high technology exports. On the other hand government R&D is positively related to the number of patents applications produced in the countries.

Key words: R&D expenditure, total factor productivity, Latin America, R&D by sources of funds, high-tech exports, patents, innovation.

1. Introduction.

Technological progress is thought to be the new most important input for economic growth since the Solow Model was developed. Technological progress is enabled by accumulation of knowledge and research and development is directly related to this production of knowledge. R&D expenditure facilitates accumulation of knowledge and therefore it contributes to technological congress which enables long-term economic growth.

Evidence suggests there is R&D expenditure has a positive effect on productivity growth. But this assumption is made for developed countries which invest a lot of resources in research and development activities. The effect of R&D expenditure in developing countries is controversial. Some argue that R&D expenditure is not a significant input for growth in developing countries and others state that the rates of return of R&D might be higher in developing countries. Some of the reasons why developed countries tend to invest more in R&D are their higher level of financial development, higher levels of IPR protection, greater capacity to deploy government resources, and high quality research institutions.

This study tries to find a positive correlation between R&D expenditure and total factor productivity growth. In addition, it tries to include as much R&D data available on developing countries. To assess the impact of research and development expenditure on innovation, high technology exports and number of patent applications are utilized as innovation outputs. The paper uses data from Latin American countries to assess this correlation. The level of high technology export is considered important for the sustainable economic growth of a country[1]. Historically, export promotion played the main role in many countries growth strategy as it has constantly been related to productivity and GDP growth. Moreover, economies with higher degree of patented products will enjoy greater independence in the market and will cope better with competition.

[1] GökmenYunus, Ufuk Turen 2013, "The determinants of High Technology Exports Volume: A panel Data Analysis of EU-15 countries". International Journal of Management, Economics and Social Sciences Vol. 2 (3), pp. 217-232

2. Literature Review

2.1 R&D measurement and types of R&D expenditure.

The first effort to standardize the meaning of R&D and determine how R&D inputs should be measured was made by OECD member countries in Frascati, Italy, 1963. In this meeting, the "Frascati Manual" was written and it has provided the basis for OECD's collecting and publishing R&D data. Since 1969, UNESCO has also published standardized R&D statistics for some developing countries, based on the Frascati guidelines.

Since 1963, the Frascati Manual has been revised many times and its 6th edition was adopted and published in 2002. After the Frascati manual, many guidelines for R&D measurement have been developed, amongst the most important ones we can find the following: “Recommendations Concerning the International Standardization of Statistics on Science and Technology”, the “Manual for Statistics on Scientific and Technological Activities, the “Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data”, and “Measuring R&D: Challenges Faced by Developing Countries”. Among other things, these guidelines establish how to measure R&D expenditure, how to define and measure personnel involved in R&D and how to measure innovation.[2]

Some of the most important classifications of R&D expenditure outlined by UNESCO and the Frascati Manual are[3]:

1- The institutional classification which includes sources of funds and expenditures in different sectors such as: government sector, business sector, higher education sector, private non-profit sector and abroad.
2- Classification by type of activity which includes R&D expenditure in basic research, applied research and experimental development.
3- Classification by fields of science which includes natural sciences, engineering and technology, medical and health sciences, agricultural sciences, social sciences, humanities.

In this study, the classification used is the institutional classification also known as classification by sources of funds. The data used is always measured as total R&D expenditure over GDP.

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[2] Organization for Economic Cooperation and Development, 2002. "The Measurement of Scientific and Technological activities, Proposed Standard Practice for Surveys on Research and Experimental Development" Frascati Manual 2002.

[3] UNESCO Institute for Statistics, 2009 .Measuring R&D expenditure. Training workshop on science, technology and innovation indicators. Cairo, Egypt.

Institutional classification or classification by sources of funds should be understood as follows[4]:

- **Government funds:** includes scientific research institutes and organizations financed from the state budget. It includes, all the departments, offices and other bodies which normally do not sell to the community, those common services, other than higher education, which cannot otherwise be conveniently and economically provided, as well as those that administer the state and the economic and social policy of the community. Studies indicate the reasoning for government funding, beyond health or defence sectors, is that the social rate of return is bigger than the private rate of return and that by subsidization governments minimize private costs, which leads to an increase of private gains (Prodan 2005)[5]

- **Higher education funds:** includes all the universities, colleges of

[4] Measuring R&D expenditure. Training workshop on science, technology and innovation indicators. Cairo, Egypt. 2009. UNESCO Institute for Statistics.
[5] Prodan, Igor 2005. Influence of research and development expenditures on number of patent application. Selected case studies in OECD countries and Central Europe, 1981-2001. Applied Econometrics and International Development. AEID.Vol. 5-4 (2005)

technology and other institutions of post-secondary education, whatever their source of finance or legal status; research institutes, experimental stations and clinics operating under direct control of or administered by or associated with higher education institutions. The research and development activities from higher education are vital to improve the science system in a country. Higher education institutions train future researches and other skilled personnel, they also collaborate with institutions from the public and private sector and can provide solutions for the economic and industrial needs of countries.

- **Business enterprise funds**: This sector covers development sectors, departments and development groups in companies. It includes all the firms and institutions whose primary activity is the market production of goods or services for sale to the general public. It also includes public enterprises.

- **Private non-profit funds:** Non-market, private non-profit institutions serving private individuals or households.

- **Abroad funds:** includes all the institutions and individuals located outside the political borders of a country, except vehicles, ships, aircraft and space satellites operated by domestic entities and testing grounds acquired by such entities; all international organisations (except business enterprises), including facilities and operations within the country's borders).

For reasons related to availability of data for Latin American counties, in this paper only government expenditure and higher education expenditure were selected.

2.2 Total Factor Productivity and R&D

Finding the determinants of TFP growth is not an easy task (Danquah, Moral-Benito, Outtara 2012), the reason why is because total factor productivity growth is hard to model empirically and because model uncertainty mixed with lack of standardized and clear theoretical guidance prevents defining its most important determinants. Nevertheless, research findings indicate that some of the most significant determinants of TFP are initial GDP and trade openness. Initial GDP tends to have a negative sign. This negative sign of initial GDP provides evidence in favor of convergence across countries in terms of the evolution of TFP. Growth rates of TFP in countries with a lower GDP tend to be higher than in counties with a higher GDP. Trade openness is positively related to total productivity growth or changes in efficiency, countries with higher degree of openness perform better when it comes to catching up with the world´s technological frontier.[6]

In spite of the problems to measure TFP, previous studies show a significant and positive relation between R&D expenditure and productivity. Ortega and Marín (2008) try to find the impact of R&D on total factor productivity and gauge the simultaneity between the two factors. They prove if higher level of R&D investment is what causes countries to increase their level of productivity or if countries which are very productive are the ones which decide to increase their levels or R&D investment or if this relation occurs at the same time. To assess this correlation, their research includes a panel data with 65 countries, with data from 1960 to 2000. It uses total factor productivity as a dependent variable and R&D spending, macro instability, ratio of commercial bank assets openness, terms of trade and FDI as independent variables. They found a significant and positive relation between TFP and terms of trade, and they

[6] Moral-Benito Enrique, Bazoumana Outtara, Michael Danquah, 2012, "TFP Growth and its Determinants: Non-parametric and Model Averaging" Swansea University

found changing degrees of significance for other variables such as FDI, openness and the income dummies included in the panel data. Ortega and Marin research also conclude that in most cases higher R&D expenditure is what makes productivity increase and it is not increase of productivity what causes an increase in R&D expenditure. This indicates that in average countries which invest more in research and development should become more productive after some time. Therefore, the evidence indicates that R&D expenditure is one of the determinants of TFP.7

Other studies (Zachariadis 2004) offer empirical evidence to support the assumption of the R&D-induced growth model, showing how R&D impacts positively the productivity growth rates in OECD counties. The Schumpeterian endogenous growth model or R&D- induced growth places entrepreneurial activities as a main driver of technological progress and output growth. Therefore, policies supporting entrepreneurial activities and technological progress might be good for growth. R&D expenditure in a country can promote the adoption of locally appropriate technologies and drive faster growth in developing countries. The technology-enhancing expenditures of developed

[7] Claudio Bravo Ortega, Alvaro Garcia Marin, "Exploring the relationship between R&D and productivity: A country level study" University of Chile

countries also have a positive effect on developing countries, because they facilities the flow of goods and ideas[8].

(Alcala, Ciccone2004) Although the debate regarding the impact of trade liberalization on economic growth remains, studies suggest a positive relation between total factor productivity and openness, terms of trade and financial development. [9] (Miller,Upadhyay 2000) A higher openness level enables countries to adopt more advanced techniques of production and consequently it promotes the growth of total factor productivity. Outward oriented countries experience higher TFP growth and human capital collaborates with trade openness to achieve this positive effect. In addition, higher exports help to overcome the constraint of foreign exchange and allow a higher level of imports which provides inputs for new production process, improvements in terms of trade has the potential to increase output.[10]

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[8] Zachariadis Marios 2004, "R&D–induced growth in OECD?" Review of Development Economics, 8 (3), 423-439.
[9] Alcalá. Francisco and Antonio Ciccone, 2004. "Trade and Productivity", The Quarterly Journal of Economics 119, 612-645
[10] Miller, and Upadhyay, 2000, "The effects of openness, trade orientation, and human capital on total factor productivity", Journal of Development Economics Vol. 63 (2000) 399-423

Foreign direct investment facilitates the transfer of technology and at the same time it promotes more growth than domestic investment (E. Borensztein, J. De Gregorio, J.W Lee 1998). Nevertheless, FDI can contribute to economic growth only when adequate absorptive capacity of the advanced technology is available in the economy. Besides the capacity to absorb advanced technology, the (level of educational attainment (level of human capital) in a country is also one of the most important determinants of FDI performance on economic growth. Higher gains of foreign direct investment are the result of higher efficiency rather than the results higher capital accumulation.[11]

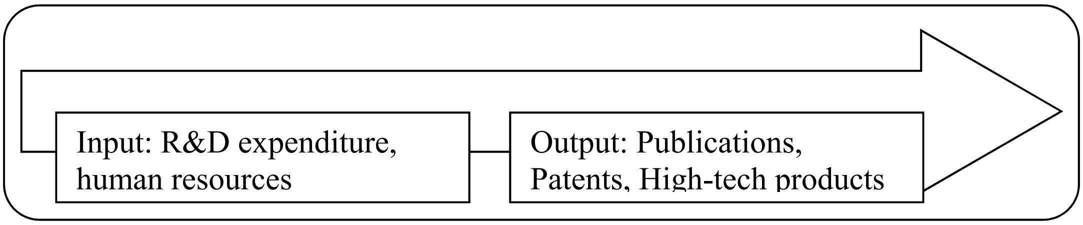
2.3 R&D performance evaluation measures

There are several ways of measuring R&D expenditure and their performance, some of the measures constantly found in the literature are those developed by Geisler (1994) which classifies R&D into: input-related approaches, output-related approaches, input-output approaches. This study falls under an input–output framework. According to the UNESCO science, technology and innovation statistics department, to be able to describe an innovation system with measurable indicators, we need input and output indicators. R&D data

[11] E. Borensztein, J. de Gregorio and J-W Lee 1998, "How does foreign invesment affect economic growth" Journal of International Economics 45, 115-135

work as input indicators and data of publications, patents and high-tech products serve as indicators of output.

The input-output approach and a linear Model for STI indicators is the following:



2.4 Impact of R&D on high-tech exports

It is expected that R&D investment will increase the share of high-tech exports; regulatory frameworks should complement research and development investment, regulatory frameworks can be more significant than the size of the market when it comes to promote of high technology exports (Braunerhjel, Thulin 2006).

(Steliana, Bogdan 2014) Previous studies show a positive relationship between R&D expenditure and the level of high tech exports. In countries within the

European Union, R&D expenditure performed by the business sector has proved to be more influential than government or public expenditures [12]. Findings imply that if the level of research and development investments is raised, especially is private expenditures are raised this could cause an increase in the level of high tech exports and as well higher competitiveness. This is consistent with the model of innovation growth strategy, which asserts that the growth of R&D investments will push forward growth in competitiveness (Oskana, Mazol)

The level of high technology export is considered of importance to achieve sustainable economic growth in a country[13]. Historically, policies related to export promotion had a vital role in many countries growth strategy because export promotion has consistently been related to productivity and GDP growth. In European countries foreign direct investment, human capital and economic freedom level proved to be have a significant positive impact on high technology exports (Gökmen, Turen 2013). (Tebaldi 2011) When it comes to the role of institutions in promoting exports, it is believed that institutions will

[12] Steliana Sandua, Bogdan Ciocanelb 2014 "Impact of R&D and Innovation on high - tech export" Procedia Economics and Finance 15 (2014) 80-90

[13] GökmenYunus, Ufuk Turen 2013, "The determinants of High Technology Exports Volume: A panel Data Analysis of EU-15 countries". International Journal of Management, Economics and Social Sciences Vol. 2 (3), pp. 217-232

tend to influence high tech exports indirectly, institutions can provide inputs for the development of human capital and foreign direct investment inflows, which play a more direct role in increasing the level of exports[14]. Because the production of knowledge and technology is driven by large economies or economies of scales, it is expected that R&D intensive production will be allocated in larger markets. (Braunerhjel, Thulin 2006) Amongst OECD countries, country size seems to not have a significant impact on high tech exports. Even though large countries have more resources to exploit economies of scale and more room for knowledge spillover it doesn't mean that smaller countries can't do the same. Country size does not indicate the allocation of production because product differentiation and specialization will allow smaller countries to specialize in specific high-tech sectors[15].

Openness impacts high tech exports positively because trade and foreign exchange liberalization are key factors for technology production. Other variables such as human capital, IT infrastructure, Total Factor Productivity, R&D expenditure, proper investment climate and the quality of institutions are

[14] Tebaldi Edinaldo 2011, "The determinants of High-Technology Exports: A Panel Data Analysis" Atlantic Journal , Vol. 39, No.4, 2011, p. 349-353
[15] Braunerhjelm Pontus, Thulin Per, 2006 "Can countries create comparative advantages? R&D expenditures, high-tech exports and country size in 19 OECD countries, 1981-1999" The Royal Institute of technology. Working paper no. 61

also expected to affect high technology exports positively (Ferragina, Pastore 2007)

2.5 Influence of R&D on patent applications

Patent data is a useful indicator to measure the production of innovation and it is believed to be the outcome of applied research and development research[16]. The role of R&D is that R&D investment promotes innovation and at the same time innovation generates economic growth. In the case of countries within the European Union, evidence shows that countries which improved innovation performance reached a higher GDP growth rate.[17] Previous research show a positive relation between R&D intensity and the number of patent registration (Huňady, Orviská, 2004).The number of researchers and the number of patents increases in countries with higher research and development expenditure. One reason could be that funding research and development activities has resulted in

[16] Papadakis, M 1993 “Patents and the evaluation of R&D” Evaluating R&D Impacts: Methods and Practice. Academic Press

[17] Ján Huňady1 , Marta Orviská, 2004, “The impact of research and development expenditures on innovation performance and economic growth of the country- the empirical evidence” CBU International Conference on Innovation, Technology Transfer and Education

a higher number of employees and led to a larger number of outputs in the form of patents.

(Prodan, 2005) An economy with higher degree of patented products will benefit from greater independence in the market and will be more able to resist competition. There is a strong and positive correlation between R&D expenditure and the numbers of patent applications, more expenditure will lead to more R&D related activities which will eventually result in a better performance in terms of patent applications. Furthermore, it has been proved that patent applications in developed countries are more related to R&D expenditure in the business sector than to domestic expenditure; therefore for developed countries it is better to measure the number of patents in terms of business expenditure than in domestic expenditures. In the case of developing countries, this relation has not been proved, but the norm is that R&D is concentrated in the government and higher education sector.

Another input to consider when developing a R&D promotion policy, is the time lag required to produce an increase in patent applications. Previous studies have found that in the United States industry there is no time-lag between R&D expenditure and patents (Hat et al 1986). In Japanese industry the time lag is about one year and a half, and to increase patent creation the Japanese experience suggest that strengthening intellectual property rights is necessary (Kondo 1999). However, others state that intellectual property protection is not at the basis of innovation in developing countries (Léger, Swaminathan2007)[18].

The effect institutions quality has on patents in developing countries is not clear. Innovation theory assumes patents systems are not very efficient in systems with poor appropriability. Nevertheless, determinants of the propensity to patent in systems with underdeveloped intellectual property rights are not clear. (Waguespack 2005) Some researchers have found that the stability of political institutions or a good institutional environment are factors which can explain the propensity to patent because inventors will take assess national policy stability when they decide to pursue inventive activity or fill out patents applications.[19] An analysis of Brazilian Industrial technological innovation shows that even if when patent systems are weak, the companies engaged in innovation activities will tend to patent their products, likewise domestic and

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[18] Léger Andreanne, Swaminathan Sushmita, 2007 "Innovation Theories: Relevance and Implications for Developing Country Innovation" German Institute for Economic Research. Discussion paper 743

[19] Waguespack, D.M., J. K. Birnir and J. Schroeder. (2005). Technological development and political stability: Patenting in Latin America and the Caribbean. Research Policy 34: 15701590.

foreign companies working in a poor institutional environment will tend to patent (Barros 2012)[20].

There is a very small amount of empirical work dealing with the determinants of patent applications. The type of studies found are ones dealing with determinants of technology production. In this paper, some of the determinants of technology are used to develop the econometric model. According to the literature some determinants of technology are investment, using gross capital formation as its indicator, trade openness (total imports and exports), and development (GDP per capita). Other variables are population and foreign direct investment (Fragerberg 1994)[21].

[20] Barros, Henrique 2012, "Exploring the use of patents in a weak institutional environment: The effects of innovation partnerships, firm ownership, and new management practices" Insper Institute of Education and Research.
[21] Fagerberg, J. (1994) "Technology and International Differences in Growth Rates" Journal of Economic Literature 32:1147-1175.

3. Aim of study

The literature provides evidence for positive relations between TFP, R&D expenditure, terms of trade and openness, in some studies financial development measured with FDI proves to be positive and in some others it is not a significant factor to foster productivity. The relevance of country size and income per capita are not normally shown in studies related to productivity, this issue will be addressed in this paper adding GDP and GDP per capital to the analysis. In addition, some studies try to discover the impact of R&D in developing countries but there not consensus on this point. The difference might be explained by the use of different samples of periods. Studies using data from the 1980 find that there is not significant relation and recent studies believe there is a positive impact of research and development activities in developing countries due to their possibilities to imitate inventions of technologically advanced countries. To address this lack of consensus, income dummies have been introduced to this study.

The literature reviewed regarding high technology exports higher R&D expenditure is positively related when expenditure is divided by sources of funds, some studies argue private R&D expenditure describes high tech exports better than public expenditures and some others argue that government expenditure is more important. Because these studies have only included countries within OECD or the European Union, this paper aims to address the same questions but using countries from Latin America.

There is not much empirical work developed related to patents application, especially using cross-country analysis. However, the empirical work available shows positive effect of R&D expenditure on the number of patent applications and differing views towards the effect of political stability and quality of institutions. Therefore, this research will conduct a cross country analysis using indicators of patents, research and development expenditures and regulatory quality in Latin American countries

3.1 Theoretical framework and Hypothesis

According to the theoretical framework and previous studies, it is expected to find a positive relationship between R&D and productivity, but this relation might vary or become insignificant according to income differences between countries.

For Latin America it is expected to find a positive relation between R&D intensity and high technology exports. The same relationship is expected for patents application.

This paper falls under the input-output approach of R&D performance evaluation measures. R&D expenditure is the input, high-tech exports and patent applications the output. The reasoning is that higher input should induce and be positively correlated to higher output (Chiesa, Masella, 1996).

4. Empirical Methodology

To test the hypothesis that R&D intensity has a positive effect on productivity in developed and developing countries a panel data methodology is used. This methodology keeps control variables such as TOT and trade from Ortega and Marin 2008 but utilizes TFP growth instead of TFP level and focuses on R&D intensity instead of R&D per capita. Income and region dummies are also added to overview the productivity performance of countries in different regions and income level.

Regarding the effect of R&D on innovation the UNESCO Model for STI indicators is used. In this model R&D expenditure acts as an input and patents and high-tech products are outputs. Studies applying this model to developing regions were not found, thus Latin America was chosen for this paper.

To test the positive impact of types of R&D on high technology exports and patents application in Latin America, panel data methodology is used. The model was constructed based on previous studies assessing performance of European countries. The studies including European countries include government and business R&D. For reasons related to availability of data this study keeps government R&D and replaces business R&D for higher education

R&D. It is also known that in developing economies the business sector doesn't invest in R&D as much as the government or higher education sectors. Finally, this study keeps independent variables such as FDI and GDP and governance indicators are added

4.1 Panel Data Methodology

The model used to measure the effect of R&D intensity on productivity is as follows:

$$\begin{aligned}\mathrm{tfpgrowth}_{i,t} = {} & \alpha + \beta_0 \mathrm{R}\&D\ intensity_{i,t} + \beta_1 \mathrm{tot}_{i,t} + \beta_3 \mathrm{trade}_{i,t} + \beta_4 \mathrm{fdi}_{i,t} \\ & + \beta_5 \mathrm{lngdp}_{i,t} + \beta_6 \mathrm{lngdppercapita}_{i,t} + \mathrm{D1} + \mathrm{D2} + \mathrm{D3} + \mathrm{D4} \\ & + \mathrm{D5} + \mathrm{D6} + \mathrm{D}_t\end{aligned}$$

The dependent variable is the growth of total factor productivity of country i at time t, independent variables include R&D expenditure over total GDP of country i at time t, terms of trade of country i at time t, trade over total GDP of country i at time t, inflows of foreign direct investment over GDP of country i at time t, log of GDP of country i at time t and log of GDP per capita of country i at time t

"D" variables are region dummy variables, where D1=East Asia & Pacific, D2= Europe & Central Asia dummy, D3=Latin America & the Caribbean dummy, D4= Middle East & North Africa dummy, D5= North America dummy, D6=South Asia dummy.

The model was developed using income dummies is as follows:

$$
\begin{aligned}
\mathrm{tfpgrowth}_{i,t} = \alpha + \beta_0 \mathrm{R\&}D\ intensity_{i,t} + \beta_1 \mathrm{tot}_{i,t} + \beta_3 \mathrm{trade}_{i,t} + \beta_4 \mathrm{fdi}_{i,t} \\
+ \beta_5 \mathrm{lngdp}_{i,t} + \beta_6 \mathrm{lngdppercapita}_{i,t} + \mathrm{D1} + \mathrm{D2} + \mathrm{D3} + \mathrm{D4} \\
+ \mathrm{D}_t
\end{aligned}
$$

The dependent variable is the growth of total factor productivity of country i at time t, independent variables include R&D expenditure over total GDP of country i at time t, terms of trade of country i at time t, trade over total GDP of country i at time t, inflows of foreign direct investment over GDP of country i at time t, log of GDP of country i at time t and log of GDP per capita of country i at time t.

"D" variables are income dummy variables, D1 is the dummy for high income countries which are not OECD members, D2 is the dummy high income countries which are OECD members, D3 is the dummy for upper middle income countries and D4 the dummy for lower middle income countries

Dt is a vector of dummy variables representing each year (1996-2012), which means that a dummy variable for each year was added in the regression. Since the dummy variables are utilized as control variables, the statistical results related with those yearly impacts will not be reported in the econometric results presented here.

This panel data includes world data from 1996 to 2012, TFP growth data was extracted from TED (Total Economy Data Base)[22], six indicators were extracted from the World Bank and used as independent variables, and these are: Research and Development Expenditure (% of GDP)[23], Terms of Trade[24], Trade (% of GDP)[25] as an indicator of openness, foreign direct investment (% of GDP)[26], GDP per capita (constant 2005)[27], (GDP constant 2005)

[22] The Total Economy Database is a comprehensive database with annual numbers of GDP, population, employment, hours and productivity for about 125 countries in the world. Since the late 1990s this database has been developed and maintained in conjunction with the Groningen Growth and Development Centre (University of Groningen, The Netherlands). As of the summer of 2007 the database has been transferred from the University of Groningen to The Conference Board and is maintained there.

Income and region Dummies were constructed according to the World Bank´s distribution of income and regions. Low income countries and countries from

[23] Expenditures for research and development are current and capital expenditures (both public and private) on creative work undertaken systematically to increase knowledge, including knowledge of humanity, culture, and society, and the use of knowledge for new applications. R&D covers basic research, applied research, and experimental development.

[24] Net barter terms of trade index is calculated as the percentage ratio of the export unit value indexes to the import unit value indexes, measured relative to the base year 2000. Unit value indexes are based on data reported by countries that demonstrate consistency under UNCTAD quality controls, supplemented by UNCTAD's estimates using the previous year's trade values at the Standard International Trade Classification three-digit level as weights. To improve data coverage, especially for the latest periods, UNCTAD constructs a set of average prices indexes at the three-digit product classification of the Standard International Trade Classification revision 3 using UNCTAD's Commodity Price Statistics, international and national sources, and UNCTAD secretariat estimates and calculates unit value indexes at the country level using the current year's trade values as weights.

[25] Trade is the sum of exports and imports of goods and services measured as a share of gross domestic product.

[26] Foreign direct investment are the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments. This series shows net inflows (new investment inflows less disinvestment) in the reporting economy from foreign investors, and is divided by GDP.

27 GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant 2005 U.S. dollars.

sub-Saharan Africa were excluded due to lack of data. A detailed list of the countries are provided in the appendix

Year dummies are included to account for the impact of each year in the model; for parsimony results of year dummies are not reported.

4.2 Panel Data Methodology for Latin America

Innovation Output measured with high-tech exports:

$$techexports_{i,t} = \alpha + \beta_0 governmentR\&D_{i,t} + \beta_1 lngdp_{i,t} + \beta_2 lngdppercapita_{i,t} + \beta(3) fdi_{i,t} + \beta_4 trade_{i,t} + \beta_5 politicalstab_{i,t} + \beta_6 regulatoryqual_{i,t}$$

The dependent variable is the share of high tech exports over total exports of country of country i at time t, independent variables includes government R&D of country of country i at time t, GDP log of country of country i at time t, GDP per capita log of country of country i at time t, foreign direct investment of country of country i at time t, trade of of country of country i at time t, political stability index of country of country i at time t and regulatory quality index of country of country i at time t.

In the second equation government R&D expenditure is replaced by R&D performed by higher education institutions, and the independent variables used in the first equation remain the same.

$$techexports_{i,t} = \alpha + \beta_0 highereducR\&D_{i,t} + \beta_1 lngdp_{i,t} + \beta_2 lngdppercapita_{i,t} + \beta(3) fdi_{i,t} + \beta_4 trade_{i,t} + \beta_5 politicalstab_{i,t} + \beta_6 regulatoryqual_{i,t}$$

In the third equation government R&D expenditure and R&D performed by higher education institutions are put together and the independent variables used in the first equation remain the same.

$$techexports_{i,t} = \alpha + \beta_0 governmentR\&D_{i,t} + \beta_1 highereducR\&D_{i,t} + \beta_2 lngdp_{i,t} + \beta_3 lngdppercapita_{i,t} + \beta_4 fdi_{i,t} + \beta_5 trade_{i,t} + \beta_6 politicalstab_{i,t} + \beta_7 regulatoryqual_{i,t}$$

Innovation output measured with amount of patent applications:

$$icoefficient_{i,t} = \alpha + \beta_0 governmentR\&D_{i,t} + \beta_1 lngdp_{i,t} + \beta_2 lngdppercapita_{i,t} + \beta_3 fdi_{i,t} + \beta_4 trade_{i,t} + \beta_5 politicalstab_{i,t} + \beta_6 regulatoryqual_{i,t}$$

The dependent variable is the innovation coefficient (resident applications per 100.000 people) of country of country i at time, independent variables includes government R&D of country of country i at time t, GDP log of country of country i at time t, GDP per capita log of country of country i at time t, foreign direct investment of country of country i at time t, trade of of country of country i at time t, political stability index of country of country i at time t and regulatory quality index of country of country i at time t.

$$icoefficient_{i,t} = \alpha + \beta_0 highereducR\&D_{i,t} + \beta_1 lngdp_{i,t} + \beta_2 lngdppercapita_{i,t} + \beta_3 fdi_{i,t} + \beta_4 trade_{i,t} + \beta_5 politicalstab_{i,t} + \beta_6 regulatoryqual_{i,t}$$

In the second equation government R&D expenditure is replaced by R&D performed by higher education institutions, and the independent variables used in the first equation remain the same.

$$icoefficient_{i,t} = \alpha + \beta_0 governmentR\&D_{i,t} + \beta_1 highereducR\&D_{i,t} + \beta_2 lngdp_{i,t} + \beta_3 lngdppercapita_{i,t} + \beta_4 fdi_{i,t} + \beta_5 trade_{i,t} + \beta_6 politicalstab_{i,t} + \beta_7 regulatoryqual_{i,t}$$

In the third equation government R&D expenditure and R&D performed by higher education institutions are put together and the independent variables used in the first equation remain the same.

This panel data includes world data from 13 Latin American countries[28] (years 1996 to 2011), variables were developed as follows:

High tech exports was divided by total exports, data was extracted from the World Bank Development Indicators Databank.

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28 The list of countries can be found in the appendix.

Innovation coefficients were extracted from the Network for Science and Technology Indicators –Ibero-American and Inter-American– (RICYT) and it represents resident patent application per 100.000 people

Data on research and development expenditures were extracted UNESCO Institute for Statistics (UIS), it includes government expenditure on research and development as a % of GDP and higher education expenditure on research and development as a% of GDP.

GDP, GDP per capita, trade, and FDI data were extracted from the World Bank Development Indicators Databank

Two governance variables were extracted from Worldwide Governance Indicators (WGI), political stability[29] and regulatory quality[30]. Estimate of governance (ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance)

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29 Political Stability and Absence of Violence/Terrorism (PV) – captures perceptions of the likelihood of political instability and/or politically-motivated violence, including terrorism

30 Regulatory Quality (RQ) – captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.

5. Results

Table 1: Total factor productivity and R&D intensity with income dummy

DEPENDENT VARIABLE: TOTAL FACTOR PRODUCTIVITY	
Regressions	1
Years	
Constant	8.54***
	(4.30)
R&D/GDP	0.50***
	(2.95)
TOT	0.009**
	(2.07)
OPENESS	0.003**
	2.03
FDI/GDP	0.007
	1.10
GDP (log)	-0.11
	(-1.59)
GDP per capita (log)	-1.02***
	(-4.83)
High income non OECD	3.21***
	(3.64)
High income OECD	2.7***
	(2.79)
Upper middle income	2.24***
	(3.24)
Lower middle income	1.44**
	(2.54)
Other statistics	
Observations	951
R2	0.26
Prob�F	0.0000

Notes: Note: t-statistics (in parentheses).

* *Significant at the 5% level

***Significant at the 1% level

Table 2: Total factor productivity and R&D intensity with region dummy

DEPENDENT VARIABLE: TOTAL FACTOR PRODUCTIVITY	
Regressions	1
Years	
Constant	6.76***
	(3.55)
R&D/GDP	0.34**
	(2.11)
TOT	0.011**
	(2.29)
OPENESS	0.004**
	(2.13)
FDI/GDP	0.005
	(0.87)
GDP (log)	-0.11
	(-1.32)
GDP per capita (log)	-0.73***
	(-5.56)
East Asia & Pacific	1.42**
	(2.37)
Europe & Central Asia	1.7***
	(3.53)
Latin America & the Caribbean	1.4***
	(2.69)
Middle East & North Africa	1.76***
	(3.20)
North America	2.3***
	(2.98)
South Asia	0.96
	(1.38)
Other statistics	
Observations	951
R2	0.26
Prob�F	0.0000

Notes: Note: t-statistics (in parentheses).
* *Significant at the 5% level
***Significant at the 1% level

The results in table 1 show a positive correlation between R&D intensity and productivity growth when including developing countries, which implies that investing in research and development activities leads to growth in productivity on a country level. R&D expenditure can increase productivity in many ways; thanks to it countries can produce goods and services which allow for more effective use of resources. Developing countries do not invest a lot in R&D, but even though developing countries cannot benefit directly from hey can benefit because of their low R&D expenditures when developing countries import products with technology incorporated and with learning embodied in them they can increase their domestic productivity and faster adapt the benefits of R&D activity to their local environment.

Regarding income dummies, high income OECD dummy, high income non-OECD dummy, upper middle income dummy and lower middle income dummy , they all show positive and significant TFP growth only when excluding low income countries.

The results in table 2 show a positive correlation between R&D intensity and productivity growth. Regarding regions dummies, from the results it can be said that East Asia & Pacific, Europe & Central Asia, Latin America and the

Caribbean, Middle East and North Africa and North America all show positive and significant TFP growth only when excluding Sub-Saharan Africa. The only region where TFP growth seems not to be significant is South Asia. In this study this region includes Pakistan, Sri Lanka and India. This paper does not explain the reasons why productivity growth in South Asia is not significant.

In table 1 and 2, independent variables reveal that terms of trade and openness affect productivity growth positively as some previous studies suggest. This happens because with higher degree of trade openness a country can adopt more advanced techniques of production and enhance their productivity and increase the TFP growth. Outward oriented countries are generally the ones that experience higher level of TFP growth. Human capital cooperates and mixes with trade openness to achieve enhance the level of productivity. In addition, higher exports reduce the foreign exchange constraint and allow countries to have a higher level of imports, these imports provide necessary inputs to improve production process; at the same time improvement in terms of trade has the power to increase output levels.

In this model, foreign direct investment is not significant. Although foreign direct investment allows for the transfer of technology, FDI can contribute to economic growth only when adequate absorptive capacity of advanced technology is available in the economy. The level of human capital (level of educational attainment) available in the country is one of the most important determinants of FDI performance on economic growth, in general terms higher benefits of foreign direct investment are the result of higher efficiency rather than higher capital accumulation. GDP is not statistically significant, which shows that the size of the economy is not a determinant of productivity growth. The negative sign in GDP per capita could mean there is convergence in the world in terms of evolution of TFP. Growth rates of total factor productivity are higher in smaller economies or countries with lower GDP per capita

Table 3: Type of R&D and High Technology Exports.

DEPENDENT VARIABLE: High Technology Exports			
Regressions	1	2	3
Years			
Government R&D/GDP	-0.28**		-0.56***
	(-2.10)		(-5.19)
Higher Education R&D/GDP		0.82***	1.04***
		(6.38)	(8.43)
GDP (log)	0.04***	0.01**	0.02***
	(5.97)	(2.30)	(4.04)
GDP per capita (log)	-0.03***	-0.01	0.007
	(-2.76)	(-1.12)	(0.63)
FDI/GDP	-0.0003	-0.004**	-0.002
	(-0.13)	(-2.21)	(-1.15)
OPENESS	0.0006***	0.0009***	0.001***
	(2.78)	(5.03)	(7.02)
Political Stability	0.06***	-0.009	0.006
	(4.77)	(-0.86)	(0.58)
Regulatory Quality	-0.005	0.02	-0.028**
	(-0.30)	(1.83)	(-2.02)
Constant	-0.66	-0.30	-0.69
	(-4.04)	(-2.78)	(-5.62)
Other statistics			
Observations	110	112	108
R2	0.35	0.46	0.49
Prob�F	0.0000	0.0000	0.0000

Notes: Note: t-statistics (in parentheses).
* *Significant at the 5% level
***Significant at the 1% level

The results in table 3 show that government R&D expenditures have not been very effective in promoting high technology exports. R&D in higher education institution proves to be much more significant to increase high technology exports. This could also mean that governments are not investing in areas related to the production of high technology products for exports.

In the case of OECD countries, country size (GDP) appears to not have a significant impact on high tech exports. Country size does not indicate the allocation of production because product differentiation and specialization allow for smaller countries to specialize in specific high-tech sectors. The positive and significant sign in GDP signals that country size is significant in Latin America when it comes to high technology exports and that production of knowledge and technology is driven by economies of scales.

Foreign direct investment proves not to be significant for growth of high-tech exports in Latin America; this might be related to the low level of human capital in Latin American countries, adequate levels of human capital is necessary to enhance the performance of FDI in an economy.

Openness impacts high tech exports positively, one of the reasons is that trade and foreign exchange liberalization are important factors for technology production. The foreign exchange gains from higher exports help to import the necessary inputs to enhance production.

In previous studies dealing with data from European countries, good investment climate and quality institutions have proved to affect high technology exports positively. In the case of Latin America, governance indicators appear not to be determinants of high tech export growth. Low performance in regulatory quality or political stability appears not to significantly affect the level of high-technology exports.

Table 4: Type of R&D and Invention Coefficient.

DEPENDENT VARIABLE: Number of patents per 100.000 people			
Regressions	1	2	3
Years			
Government R&D/GDP	4.16**		4.97***
	(2.51)		(2.88)
Higher Education R&D/GDP		-0.81	-3.05
		(-0.43)	(-1-54)
GDP (log)	0.16**	0.29***	0.21**
	(1.93)	(3.44)	(2.40)
GDP per capita (log)	-0.17	-0.12	-0.30
	(-1.08)	(-0.71)	(-1.67)
FDI/GDP	0.01	0.03	0.02
	(0.50)	(1.20)	(0.75)
OPENESS	-0.004	-0.003	-0.006**
	(-1.62)	(-1.16)	(-2.14)
Political Stability	0.47***	0.75***	0.63***
	(3.06)	(4.71)	(3.43)
Regulatory Quality	0.05	-0.31	0.09
	(0.23)	(-1.90)	(0.45)
Constant	-1.69	-4.91***	-1.62
	(-0.87)	(-3.15)	(-0.84)
Other statistics			
Observations	98	102	98
R2	0.43	0.40	0.44
Prob�F	0.0000	0.0000	0.0000

Notes: Note: t-statistics (in parentheses).
* *Significant at the 5% level
***Significant at the 1% level

The results in table 4 show that government R&D expenditures are positively related to the number of patent applications in a country, whereas expenditures by higher education institutions are not statistically significant to predict the number of patent application in a country. The reason why government R&D is significantly related to the number of patents but not related to high-tech exports could be that governments R&D expenditures are concentrated in areas that are more prone to the creation of patents, such as health, environment, defense or agriculture. The dynamics and structure of patenting offices in Latin American countries can also explain the patterns of patent applications amongst countries; however, this topic is not covered in this paper.

The negative sign in GDP shows that in Latin America innovative capacity is concentrated in larger economies. FDI and trade openness seem not to be significant for the number of patents in a country.

The effect institutions have on patents in developing countries is not clear. Nevertheless, as argued in previous studies political stability is positively and significantly related to the number of patent applications in Latin America. Waguespack 2005 argues that the stability of political institutions or the stability of the institutional environment are factors which can explain the propensity to patent because inventors will analyze and consider national policy stability when they decide to get involved in inventive activities or try to patent. Regulatory quality seems to be not significant, which supports previous studies (Barros 2012) arguing that even when a patenting system is underdeveloped, companies which engage in innovation activities will patent their products, and likewise local and foreign companies in an undeveloped institutional environment will also tend to patent.

6. Conclusion

This research offers evidence to state that research and development expenditures promote productivity growth. R&D and productivity are positively correlated and even if high income countries benefit more because of their higher R&D intensity, developing countries can benefit indirectly through a spillover effect.

Regarding income dummies, high income OECD dummy, high income non-OECD dummy, upper middle income dummy and lower middle income dummy , they all show positive and significant TFP growth only when excluding low income countries. Regarding regions dummies, from the results it can be said that East Asia & Pacific, Europe & Central Asia, Latin America and the Caribbean, Middle East and North Africa and North America all show positive and significant TFP growth only when excluding Sub-Saharan Africa. The only region where TFP growth seems not to be significant is South Asia. It can be stated that income levels are a more useful indicator to account for growth differences among countries because differences within regions are too wide and this doesn't give a lot of room to make general statements.

R&D expenditures and the input-output Model for Latin America:

This study shows that Government R&D expenditure has not been very effective in promoting high technology exports in Latin America. R&D in higher education institution proves to be more significant to increase high technology exports. In the case of Latin America, governance indicators appear not to be significant to foster high-tech export growth.

Furthermore, this paper shows that government R&D expenditures are positively related to the number of patent applications in a country, whereas expenditures by higher education institutions are not statistically significant to predict the number of patent application in a country. Political stability is positively and significantly related to the number of patent applications in Latin America. As shown inventors will take into account national policy stability when they decide to engage in inventive activity or seek patent, therefore political stability and the quality of the institutions are factors which can explain the tendency to patent. Regulatory quality doesn't seem to have an impact on the level of patent applications.

Currently, there is more data to assess correlations between types of R&D expenditure and innovation outputs in developing regions. In the case of Latin America, Higher Education R&D appears to be promoting high tech exports, and Government R&D shows to be positively related to the number of patent applications. Regarding governance, political stability proves to be important for patent creation.

Nevertheless, using this data to make policy recommendations is still risky. Many developing countries only have incipient R&D systems. This is likely to change in the future because of UNESCO efforts to provide guidelines to developing countries about how to overcome their challenges measuring R&D.

Future Research: Patent applications might also be affected by the particular characteristics of patenting offices and degree of intellectual property rights in developing countries. These factors are not taken into consideration. Another factor not taken into consideration is the real value or nature of patents. More comprehensive reports of R&D data from developed and developing countries will enable to understand more extensively the dynamics of R&D, including variables such as R&D by type of activity (basic, applied, experimental) or by field of study (engineering, natural science, social science, etc).

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8. Appendix

Countries used for regressions in Table 1 and 2			
Albania	Denmark	Latvia	Slovak Republic
Algeria	Dominican Republic	Lithuania	Slovenia
Angola	Ecuador	Luxembourg	South Africa
Argentina	Egypt	Macedonia	South Korea
Armenia	Estonia	Madagascar	Spain
Australia	Ethiopia	Malawi	Sri Lanka
Austria	Finland	Malaysia	St. Lucia
Azerbaijan	France	Mali	Sudan
Bahrain	Georgia	Malta	Sweden
Bangladesh	Germany	Mexico	Switzerland
Barbados	Ghana	Moldova	Syria
Belarus	Greece	Morocco	Taiwan
Belgium	Guatemala	Mozambique	Tajikistan
Bolivia	Hong Kong	Netherlands	Tanzania
Bosnia & Herzegovina	Hungary	New Zealand	Thailand
Brazil	Iceland	Niger	Trinidad & Tobago
Bulgaria	India	Nigeria	Tunisia
Burkina Faso	Indonesia	Norway	Turkey
Cambodia	Iran	Oman	Turkmenistan
Cameroon	Iraq	Pakistan	Uganda
Canada	Ireland	Peru	Ukraine
Chile	Israel	Philippines	United Arab Emirates
China	Italy	Poland	United Kingdom
Colombia	Jamaica	Portugal	United States
Costa Rica	Japan	Qatar	Uruguay
Côte d'Ivoire	Jordan	Romania	Uzbekistan
Croatia	Kazakhstan	Russian Federation	Venezuela
Cyprus	Kenya	Saudi Arabia	Vietnam
Czech Republic	Kuwait	Senegal	Yemen
Czechoslovakia	Kyrgyz Republic	Singapore	Zambia
			Zimbabwe

Countries used for regression in table 3 and 4		
Country	Country code	Country number
Argentina	ARG	9
Bolivia	BOL	32
Chile	CHL	43
Colombia	COL	50
Costa Rica	CRI	53
Ecuador	ECU	66
Guatemala	GTM	93
Mexico	MEX	143
Panama	PAN	174
Paraguay	PRY	184
Peru	PER	176
Trinidad and Tobago	TTO	225
Uruguay	URY	234