TRAPPED IN THE MIDDLE. DEVELOPMENT, R&D AND THE NATIONAL INNOVATION SYSTEM

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Documento de trabajo

DT IDEI 19 -2016

Documento presentado en SPRU 50th Anniversary Conference

IDEI Instituto de Industria

Universidad Nacional de General Sarmiento

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09/09/2016

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RESUMEN

The objective of this paper is to analyse how national innovation systems (NISs) determines the impact of investments in capabilities on development. Innovation studies agree on the existence of a positive relationship between expenditures on R&D and qualified human resources (QHR) –two traditional proxies of capabilities- and economic growth. Based on a NIS approach, this relationship has found two causal interpretations. One group of contributions affirms that investments in capabilities lead to the development of the NIS and this to growth and development (a convergence hypothesis). The second stream of the literature sustains that development requires specific NISs (a specificities hypothesis) since investments in R&D and QHR will impact differently on development depending on the country. Furthermore, R&D and QHR mean different activities and skills depending on the specificities of the national system. Both hypotheses will be tested in this paper. The empirical approach is based on the econometric analysis of investments in R&D and QHR, and the evolution of the GDP in 81 countries (90% of the world product and population), for the period 2000-2014. Results lead to reject the convergence hypothesis and to confirm the existence of different impacts depending on the countries' specificities. Moreover, results provide evidence regarding the existence of increasing returns of investments in capabilities, once they have reached a minimum threshold of expenditure. On the one hand, R&D and QHR do not impact on GDP growth among less developed countries. On the other, they do impact among medium and high income nations, but with a greater positive effect among the latter ones. We conclude that development demands systemic efforts in the pursuit of an environment capable of promoting learning processes and competence building, where R&D is a consequence –not a cause- of the level of development.

Palabras clave: national innovation system, development, capabilities, R&D

Introduction

The objective of this paper is to analyse to what extent national characteristics determine the impact of investments in knowledge creation on growth and development. The methodological approach is based on the analysis of investments in research and development (R&D) and efforts in the training of qualified human resources (QHR), and how they impact on the growth level of the gross domestic product (GDP). Even though literature under the national innovation system (NIS) approach has long considered these activities a key to explain absorptive and technological capabilities (Lundvall, 2007; Narula, 2003; Nelson y Dahlman, 1995), scarce attention has been paid to the relationship between the environment and the impact of these investments on growth. If innovation is a systemic process, then the impact of investments in the creation and application of knowledge will depend of the system sounding and supporting R&D investments and QHR training. The objective of this paper is to contribute to the NIS literature by providing evidence regarding systemic nature of R&D and QHR and how different systems will lead these variables to impact also differently. At the same time, it tends to provide some insights to policy making by analysing the actual impact of R&D and QHR on economic growth.

The theoretical framework is based on the NIS approach, given the systemic dynamics between the generation, application and dissemination of knowledge and the level of development. Literature on NISs -and most of innovation studies- agrees on the existence of a positive relationship between R&D investments and QHR training and economic growth (see for example: Edquist, 2001, 2004; Freeman, 1995, 2002; Lundvall, 1992; Nelson, 1993).On the one hand, R&D activities are inputs to the science, technology and innovation mode of learning (Jensen *et al.*, 2007), to the extent that contribute to the creation of knowledge and its transformation into innovation. On the other hand, the relative level of people with tertiary education is a good proxy of the other mode of learning, based on training and experiencing, which is a more informal way of knowledge creation. Together, these two variables should be a good approximation to the investments in the creation of knowledge, R&D in terms of technological capabilities and QHR in terms of skills.

There exist at least two positions regarding how these investments lead to development. One group of contributions affirms that investments in capabilities lead to the development of the NIS and this to growth and development (a convergence hypothesis) (e.g.: Archibugi y Coco, 2004a, b; Edquist, 2001; Fagerberg y Srholec, 2008; Viotti, 2002). From this perspective, capabilities are thought to be the key to close the technological gap between developed and developing countries. The second stream of the literature discusses the convergence hypothesis and sustain the NIS determines the impact capabilities have on growth (a specificity hypothesis) (e.g.: Arundel *et al.*, 2007; Castellacci, 2011; Lee y Kim, 2009a; Lundvall, 2007; Natera, 2016; Nelson y Dahlman, 1995). Under this literature, national initial conditions and structural features define diverging growth performances.

The aim of this paper is to test both hypotheses. The empirical approach is based on the econometric analysis of investments in R&D and training of QHR, and the evolution of the GDP in 81 countries with different levels of development, which account for more than the 90% of world product and population, for the period 2000-2014. The database was made using World Bank and UNESCO data. Under the convergence hypothesis, both variables would impact on growth regardless the country's level of development. Under the specificities hypothesis, impacts will differ.

Results partially confirm the hypotheses. On the one hand, a positive relationship between investments and growth, regardless of the level of development is confirmed. This is consistent with the hypothesis of convergence. However, the analysed data also provide evidence about the existence of increasing returns, once a minimum threshold of expenditure is reached. The impact of R&D and QHR on growth is higher among most developed countries than among middle income ones. Conversely, R&D and QHR do not impact on GDP growth among less developed economies. These results lead to confirm the hypothesis about specificities. Thus, from an aggregate perspective, the evidence shows heterogeneity in the relationship between capabilities and economic impact, which is consistent with the NIS literature in the sense that each country has to search for its own development process.

This paper is structured as follows. After this introduction, section two presents the theoretical framework and discusses the convergence and the specificities hypotheses. The third section presents the methodology and data. In the fourth section the model is applied and results are analysed. Finally, some conclusions are provided.

2. National innovation systems: convergence and specificities

2.1. The convergence hypothesis

Under the NIS approach, and the same within most innovation literature, there is a generalized consensus regarding the nonlinearity of the development process. This consensus is based on the recognition of innovation as a key to development, which is the result of an interactive and policausal process determined by multiple agents and institutions. The translation of these postulates into empirical analysis has led to two types of studies. On the one hand, there is a group of contributions that analyse development in terms of distances of key dimensions between developed and developing countries. These studies are based on the concept of catch up between less and more developed nations and conclude that developing countries will close gap by means of promoting the development of the NIS (e.g.: Albuquerque, 1999; Archibugi y Coco, 2004a, b; Edquist, 2001; Fagerberg y Srholec, 2008; Fagerberg y Verspagen, 2007; Filippetti y Peyrache, 2011; Godinho *et al.*, 2004; Viotti, 2002). However, although evidence corroborates this postulate (higher levels of investment in R&D and QHR are observed among high-income countries), investments and capabilities are not independent from the rest of the system.

These types of approaches are based on a convergence hypothesis, where investments in capabilities are expected to lead to the development of science and technology and this to growth. In this respect, the implicit assumption is that the link between investments and growth is independent from the level of development of the innovation system. For instance, Archibugui and Coco (2004b) propose the ARCO technology index to measure technological capabilities of countries and their impact on product growth. The index is based on an averaged aggregation of variables that account for the creation of technology, the technological infrastructure, and the development of skills. Based on the ranking derived from the index, the authors identify four types of countries -leaders, potential leaders, latecomers and marginalized- and found a positive and significant relationship between the ARCO and the level of GDP growth. The linear dimension of perspectives like this one lays, firstly, on the implicit assumption of perfect substitution between aspects of technological capabilities –as if an increase in the number of patents could compensate a decrease in the literacy rate. Secondly, on the idea that equal increases in the level of the composite indicator will impact equally on growth (an average coefficient), whether this relationship is being analysed in Kenya or Germany.

To solve the first problem, other studies weight the dimensions. For instance, Fagerberg and Srholec (2008) perform a factor analysis to reduce and weight a set of relevant dimensions related to GDP growth and found that capabilities associated with the NIS are key elements to explain growth of nations[1]. Under this approximation, although the problem of substitution is relatively solved, by assigning different weights to variables and by allowing different variables to impact with different intensities, the linearity of the analysis remains since an average level of impact for all countries is expected. In this respect, although the study includes variables to control countries' specificities, they do so in terms of changes in the intercept level and not on the marginal impact of independent variables (the pendent of the estimation).

[1] They also found that capabilities related to governance, openness and political stability impact positively on GDP growth too.

There is a third type of studies, based on the idea that a specific approach for developing countries is required. This type of studies tackles the second problem by means of proposing a conceptual framework adjusted to the specificities of innovation, capabilities and the process development. For instance, Edquist (2001) and Viotti (2002) proposed the concepts of System of Innovation for Development (SID) and National Learning Systems (LIS), respectively. The two approaches are based on the idea that developing countries should concentrate their investments in different areas than developed ones.

Both from the SID as the LIS perspective, the assumption is that there are steps that developing countries must complete to achieve the "state" of developed ones. Particularly, they should invest in embodied technology and basic skills before considering more complex investments in capabilities such us those associated with R&D. Thus, according to these approaches development depends on (and is limited to) investing in the acquisition and adaptation of the technology developed elsewhere, at least at the initial stages. Under these conditions, the stage of development will be determined by the distance to the international technological frontier: developing countries are below this border, while countries above are developed ones (Edquist, 2001). The place of each country in this general context determines the type of the required innovation. While developing economies should specialize in incremental process innovations and devote efforts to absorb and eventually adapt the technology, developed countries are responsible of radical innovations associated with creating new knowledge and products for the world. A similar reasoning is observed in Viotti's (2002) work regarding the existence of passive national systems of learning and innovation (LIS) where development is associated with the ability of a LIS to promote actions and investments to close the gap with respect to developed countries (called the actual national innovation systems).

Although this third approach assumes that investments in capabilities will impact different among developing countries, they also assume that technologically complex investments will not be profitable –will not impact on growth- among developing countries. *A priori*, the SID and LIS perspectives represent a step forward against the ideas of undifferentiated convergence, present in contributions such as Albuquerque and Coco (2004a, b) and Fagerberg and Srholec (2008). However, they share some limitations with the convergence group. Firstly, they do not exceed the linear reasoning where equal inputs lead to equal outputs (as if all developing world were all the same). Secondly, they also state a linear sequence between a developmental stage and the next one, which means that less developed economies must pass through processes of productive reconfiguration that allow them to resemble their structures to those prevalent in developed countries. Thirdly, their recommendations could lead to perpetuate underdevelopment. If developing countries assume the role of “technology adopters” and invest only in that direction, then they will always be below the international technological frontier. In a nutshell, the linear view in this case has to do with a step-based comprehension of development in the sense that developing countries should move from “good adopters” or “learning systems” to radical technology creators or national systems of innovation (see Erbes y Suarez, 2014 for an extended discussion).

Summing up, evidence verifies the positive and significant relationship between investments in capabilities and growth. This is a fact that cannot be denied. Neither can be denied that most of least developed countries lack basic capabilities –such as productive ones- which account for the need to invest in the most basic dimensions of technological capabilities –such as literacy or connectivity- before expecting more complex investments -such as R&D- to impact on growth (Lee, 2013a). However, this linear view has several limitations which applied to both developed and developing countries. The configuration of the system and the process of competence building are the result of path dependence trajectories of investments in knowledge creation and application. Hence, capabilities should be analysed in relation to the specific NIS. The higher the articulation of these investments, the higher their impact on growth.

2.2. The specificities hypothesis

As it was mention before, there is another group of studies which sustains that development depends on specific inversions to modify the system. To the extent that each innovation system is unique, there is not a unique set of dimensions that would lead the country into a development path (e.g.: Arundel *et al.*, 2007; Castellacci, 2011; Castellacci y Archibugi, 2008; Castellacci y Natera, 2013; Desdoigts, 1999; Fagerberg *et al.*, 2007; Freeman, 2002; Lee y Kim, 2009a; Lundvall, 2007; Natera, 2016; Nelson y Dahlman, 1995). Hence, investments in capabilities will impact differently on different system structures. In this case, development depends of promoting a specific NIS capable of triggering development. According to the former group, there is an automatic and linear relationship between investments and impact on growth (a convergence hypothesis), according to this one, the impact will depend on the characteristics of the NIS (a specificities hypothesis).

This group of studies are based on the idea that investments in capabilities will impact differently depending on the specificities of the national innovation system. For instance, the national context and the location of the country within the global capitalism will determine the type of external insertion and the possibility of taking advantage of global growth or avoid global recessions

(Freeman, 1995). The need to take other variables into account is also highlighted by Lundvall (Lundvall, 2007; Lundvall y Lam, 2007), who states that the particular characteristics of the productive structures in terms of the required capabilities to translate knowledge into innovations explain the differential levels of development. Accordingly, Nelson y Dahlman (1995) explain that the divergent patterns of growth among developing countries is the result of differential levels of social absorption capabilities conditioned by the macroeconomic environment, the institutional set ups and the role of the government. Meanwhile, Desdoigts (1999) sustains that geographical, cultural and institutional variables impact the economic structures which explains the different patterns of national growth. In short, there is a generalized consensus within the NIS approach regarding the impact of national specificities on the relationship between investments in capabilities and growth.

Studies based on the idea that national specificities determine the relationship between capabilities and growth are mostly country-case studies, hardly comparable between each other (see Dutrenit y Sutz, 2014for a compilation of Latin American country cases; and Edquist y Hommen, 2009 for a compilation of European and Asian country cases). However, the comparative analysis shows that all of them highlight the historic nature of the process of competence building and how specific aspects of the NIS fostered or blocked development at specific moments of time. Similar conclusions can be found in Patel and Pavitt (1994).

The comparative analysis also shows that the impact of similar policies and similar types of investments differs across nations. Freeman (2002) refers to this as the impact of the coherence of the subsystems on the individual actions and policies. According to this author, the history of catch up (or lagging behind) at the global level is explained by processes of coherence (and incoherence) within the national systems in terms of key aspects of development, such as education, science and technology, political situation, productive structure, social characteristics, etc., and how that articulated or not with the international arena (first industrial revolution, post-war periods, cold war, etc.). Extrapolating these ideas up to date, there are not *a priori* elements to assume that equal variations in the levels of investments in capabilities in Kenya and Germany will impact equally on the growth level of each country. On the contrary, there are good reasons to expect the impact to depend on the specific type of investment and the specific characteristics of the NIS.

More recently, the availability of large international databases allow a new set of cross-country studies which although less based on the NIS approach, provide comparable cross-country analyses which verified the postulate of different impacts depending on the level of development. This is the case, for instance, of the contributions of Castellacci (2008) and Castellacci and Archibugi (2008)[2]. The authors discuss the existence of differential impacts based on the idea of convergence clubs (Durlauf *et al.*, 2005), which postulates that structural characteristics and initial conditions explain the different patterns of growth rates of countries. Based on cluster techniques and econometric estimations, the authors identify groups of countries associated with different dynamics of technological change (advanced, followers and marginalized). The groups have differences in terms of their abilities to generate and acquire technological knowledge, which allow processes of catch up among follower countries and processes of lagging behind (an increase in the technological gap) among marginalized ones.

Another interesting analysis is the one performed by Natera and Castellacci (2011, 2013). The authors postulate that innovative capabilities (R&D, S&T, innovation activities, etc.), technological capabilities (infrastructure, trade, QHR) and the level of national income (GDP) coevolve over time. Then, they test this triple relationship in a large set of developed and developing countries and found strong coevolution among OECD member countries, a week relationship among least developed ones and an intermediate situation in middle income countries, which are characterized by high levels of absorptive capabilities but low levels of innovative ones. The authors warn about that existence of virtuous circles in which countries with higher technological capabilities access to more complex technologies, while countries with lower capacities are relegated to low-tech production processes that reproduce less developed dynamics.

Differential impacts of capabilities on growth are also found in the work of Lee and Kim (2009a). The authors analyse the impact of different types of capabilities on the growth on nations, under the hypothesis that different capabilities matter for different country groups in relation to development levels. The results corroborate the hypothesis: complex capabilities (R&D, QHR and patents) have a positive and significant impact on most developed countries while the association is very weak among least developed ones. Among the later, basic capabilities such as secondary education have a significant and strong association with growth. As expected and similar to Castellacci (2008) and Castellacci and Archibugi (2008), middle income countries present an intermediate situation. Later on, Lee (2013a) will state that this intermediate situation is associated with the middle income trap, where countries are stacked in a situation of a level of technological capabilities that are not enough to compete with developed nations but high enough to impact on wages and prevent them to

[2]It is worth mentioning that by including the convergence clubs approach, Archibugui's work related to the ARCO index moves to a more complex analysis of growth and development, although he will get back to analysis based on composite indicators in more recent works (e.g.: Archibugi *et al.*, 2009).

compete based on low costs. Therefore, and coming back to the specificities hypothesis, the characteristics of the NIS determines the impact of capabilities on growth to the extent that there will be different capabilities triggering different innovation processes attached to different structures of supply (production) and demand (income level).

In short and from a general Schumpeterian perspective, there is no doubt that the same investments will lead to different impacts in different countries. The ability to access more complex technological clubs that result in higher levels of per capita income is associated with the existence of high levels of absorption and innovative capabilities. The heterogeneity in the distribution of knowledge across countries and the differential constraints NIS face when investing to access them explain the divergent paths between countries, rather than the possibilities of convergence.

3. Empirical approach and hypotheses

3.1. The hypotheses

The objective of this paper is to test the two approaches and postulates identified in the literature. In order do so, capabilities will be approximated with R&D investments and QHR stock to total population. The selection of the variables responds to several reasons. Firstly, they are usual proxies of technological efforts and skills, respectively, within the different studies reviewed in section 2 and within innovation studies generally speaking. Secondly, they are two of the most monitored indicators of STI development by policy makers. This way, results are expected to contribute both to theoretical and practical debate about capabilities, growth and development. Thirdly, the use of single variables (instead of composite indicators) avoids the substitution problem discussed in section 2.1. Of course, it also limits the analysis to the countries that report this information and excludes other relevant investments such as embodied technology. However, we hope that future research on the subject will allow extending the dimensions of capabilities to other types of investments. At the same time, and as we shall discuss later on, control variables will be added in order to control for omitted information.

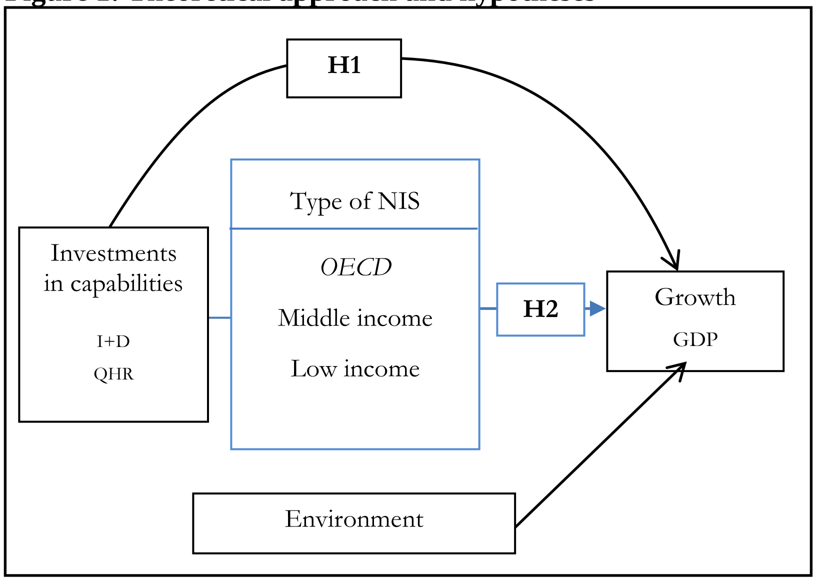
Figure 1 summarizes the theoretical arguments and hypotheses. H1 refers to the convergence hypothesis discussed in section 2.1. Accordingly, the growth rate of investments in capabilities (R&D efforts and QHR training) has a positive impact on the level of GDP growth, subject to environmental characteristics (area, population, productive structure, etc.). This hypothesis can be formulated as follows:

H1: *An increase in the investments in capabilities positively impacts on GDP growth;*

H1.a. *An increase in the investments in R&D positively impacts on GDP growth;*

H1.b. *An increase in QHR training positive impacts on GDP growth.*

Figure 1: Theoretical approach and hypotheses



Source: own elaboration.

Measuring development is not an easy task. However, there is a generalized consensus regarding the fact that development implies growth with equity, which leads to a systematic and generalized improvement in the quality of life of each stratum of society (Johnson *et al.*, 2003; Myrdal, 1973). Following this literature, per capita GDP was selected since it is usually a good approximation to the level of development, to the extent that it is simultaneously associated with variables that account for human development (mortality , literacy, health , income, etc.) and also with variables related to economic growth (competitiveness, productivity, employment, etc.).

Testing H1 allows the analysis of the convergence postulates, and contributes to a better understanding of the behaviour of key indicators of technological development. In this regard, although there is a generalized consensus about the positive impact of capabilities on growth -which leads to expect H1 to be verified-, evidence is scarce regarding the direct impact of R&D and QHR on GDP growth, and this justifies H1.a. and H1.b. The verification of these hypotheses would imply that there is an average impact of investments in capabilities on GDP growth, which is relevant to all countries. More specifically, it would mean that there is a relevant and meaningful level of average impact of investments to Kenya, Vietnam, Argentina or Germany, which is independent of the differences between these national innovation systems. Given the literature discussed in section

2.2. and the evident differences between these countries, there are good reasons to expect different average impacts and this justifies H2, which can be formulated as follows:

H2: *The impact of an increase in the investments in capabilities on GDP growth increases as the level of development of the NIS increases;*
H2.a: *The impact of an increase in the investments in R&D on GDP growth increases as the level of development of the NIS increases;*
H2.b: *The impact of an increase in the training of QHR on GDP growth increases as the level of development of the NIS increases.*

According to section 2.2, investments in developed NIS will impact higher on growth since they are part of a more systemic process of knowledge generation, articulated with a denser network of institutions, a larger scale and previous learning processes. In other words, these countries have higher capabilities to absorb, implement and transform knowledge. Continuing with the example presented above, Kenya, Vietnam, Argentina and Germany have different institutional set ups, different accumulated capabilities and assets, different productive structures and specific trade specialization patters. Hence, there are good reasons to expect a 1% increase in R&D or QHR to impact differently on the growth rate of the GDP of each country. This means that developed countries have more developed innovation systems, then R&D and QHR investments impact higher than among less developed ones.

Finally, it is important to highlight that the confirmation of H2 cannot be considered an argument to recommend lower levels of investment in capabilities among developing countries or the concentration of R&D and QHR in developed ones. On the contrary, the confirmation of H2 would point to the need of higher levels of investments among the former since the impact is less than proportional (a 1% increase in R&D expenditure in Germany will impact higher on GDP than in Argentina). In a nutshell, more-than-proportional efforts will be required to close the gap.

3.2. The dataset

In order to test the hypotheses, a model that relates GDP growth and capability investments will be constructed and applied to a set of 81 countries with information for the three main variables: GDP, R&D and QHR. The database was constructed from the information provided by international databases and standardized indicators, which ensures the comparability of the variables to use[3].

[3] See appendix A for a detailed description of sources, variables and countries.

Although the empirical analysis is based on a reduced number of cases (international databases account for around 175 countries with information about national accounts), they are all the countries that reported information about science and technology, education and economic performance for at least one year within the period 2000-2014 (last available year for most of the countries). In terms of participation, the included cases account for around 90% of the world GDP and population in 2014[4]. To some extent, the database is biased to those more developed countries, which are the ones with a more complete statistical system, and this could lead to overestimate the results. However, the number of observations (and the list of countries) are similar to the one used in other studies, which improves the comparability of the results (e.g.: Castellacci, 2011; Fagerberg y Srholec, 2008; Fagerberg *et al.*, 2007; Lee y Kim, 2009b).

The period under analysis is 2000-2014 and it was segmented into five moments, based on average values: 2000-02, 2003-05, 2006-08, 2009-11, 2012-14. This combination of countries and average annual values maximize the total number of observations (285) and improves the representation of countries with different income levels. It is worth mentioning that although this selection includes the 2008 financial crisis (an exogenous shock to several economies), there are good reasons to expect the variables to be analysed to impact in the long term and, most probably, only be significantly modified also in the long term. For instance, a 1% increase in the growth rate of qualified human resources demands changes in the education system (assuming that the quality of the formation remains the same). Therefore, the selected time window maximizes the possibility of capturing changes in the variables and how they impact each other.

Summing up, the analysis includes the largest countries in the world, which explain most of the dynamics of the different geographical regions. It also accounts for their economic evolution in a recent period and constitutes a first approximation to the relationship between capability investments and growth, which could be enriched and extended with the increase in the available information.

3.3. The characterization of the NIS

3.3.1. Country classification, growth and capabilities

The first challenge to test the hypotheses consists of establishing a taxonomy of innovation systems in order to analyse quantitatively the impact of investments in R&D and QHR. The difficulty lays on the availability of information and the heterogeneity of realities. For the purposes of this paper

[4] Based on the World Bank estimations and countries with available information.

and to focus efforts on the analysis of investments, a traditional classification was selected and countries where grouped as follows:

- OECD: are those countries member of the Organization for Economic Co-operation and Development.
- Middle income: are those countries non-OECD members with a per capita GDP higher than US$ 4126, which is the World Bank classification for upper middle and high-income countries. Since OECD members were excluded, all countries are part of the middle income group.
- Low income: are those non-OECD member countries with a per capita GDP lower than US$ 4126, which is the World Bank classification for low and low-middle income country.

The rationale for this selection reflects the fact that this is a widespread and simple estimate for all countries and with a high explanatory power with respect to the variability between levels of development of the NIS. The complete list of countries and their classification is provided in Appendix A.

Table 1 presents the relationship between the classification and the geographical localizations. Accordingly, most of OECD countries are located in Europe –more specifically, the European Union- and North America. Middle income countries are those from the south Latin America and low income countries are located in north East Asia and Africa. Although not presented in the table, the dynamic perspective shows that over the period under analysis, Israel, Estonia and Slovenia were added to the OECD group since their became members in 2010. Bulgaria, Belarus, Colombia and Servia changed from the low to middle income group since their GDP per capita passed the cut line during the period. Therefore, only 7 out of 81 countries changed categories, which account for the structural nature of the used criteria.

Table 1: Income level and regions – 2012-2014

% to income classification					% to regional classification			
	OECD	**Middle income**	**Low income**	**Total**	**OECD**	**Middle income**	**Low income**	**Total**
Latin America and the Caribbean	6.1	31.8	15.4	**16.0**	15.4	53.8	30.8	**100**
Africa	3.0	9.1	34.6	**14.8**	8.3	16.7	75.0	**100**
Asia and the Pacific	12.1	18.2	34.6	**21.0**	23.5	23.5	52.9	**100**
European Union and North America	66.7	27.3	0.0	**34.6**	78.6	21.4	0.0	**100**
Rest of Europe	12.1	13.6	15.4	**13.6**	36.4	27.3	36.4	**100**
Total	**100**	**100**	**100**	**100**	**40.7**	**27.2**	**32.1**	**100**

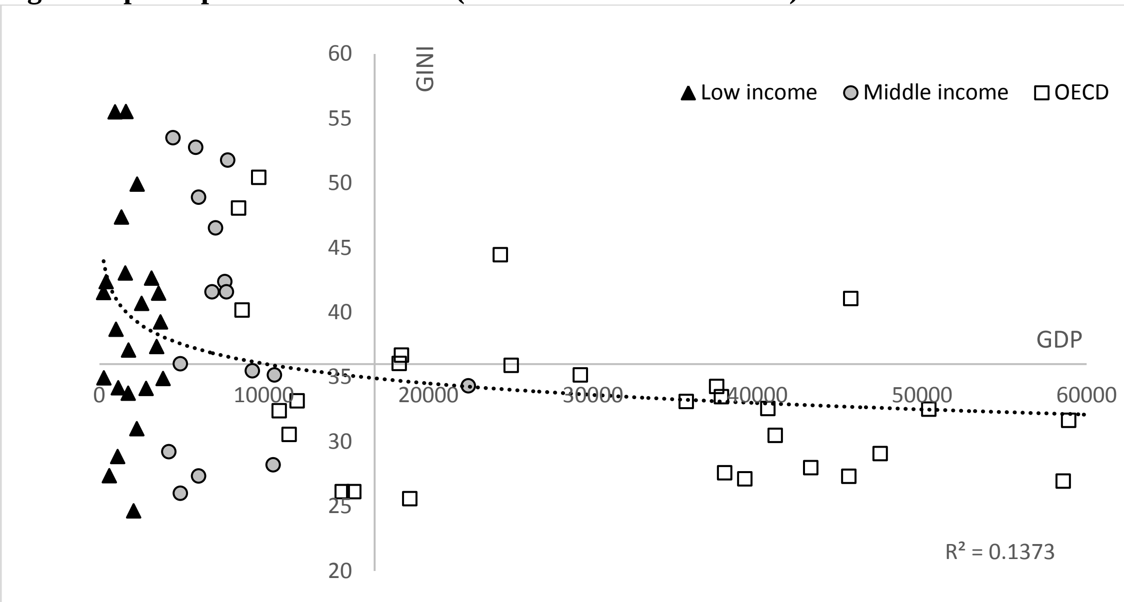
Notes: Obs.: 81. Source: own elaboration.

As it was mentioned before, there is general consensus about the fact that development is related to growth with equity (Johnson et al., 2003; Myrdal, 1973) and the fact that investments in technological and absorptive capacities contribute to that goal (Fagerberg and Srholec, 2008; Narula, 2003). In this sense, per capita GDP is the most common measure of development, but not just because it constitutes an average level of income but because its strong correlation with other key variables associated with social welfare (mortality, literacy, health, income, etc.) and economic growth (competitiveness, productivity, employment).

Figure 2 illustrates the relationship between per capita GDP and the GINI index, which is a common measure of equity. Based on this figure, countries in the first positions (the OECD group) are usually called developed countries, while those at the bottom of the ranking are called developing ones (middle- and low-income countries). Wherever the distinction between the top, the centrum and the bottom of the ranking is traced, there is no doubt that some countries are more developed than others, even when the correlation between GDP per capita and the different dimensions of welfare will not be the same for each country[5]. This correlation explains our selection of income levels as a proxy of development, being aware that the specific relationship between per capita GDP and each single dimension of development could vary between countries.

[5]Cuba, for instance, has low levels of motherhood and child mortality with low levels of GDP per capita, while Brazil has relatively higher levels of GDP with also higher levels of poverty.

Figure 2: per capita GDP and GINI (absolute values 2012-2014)

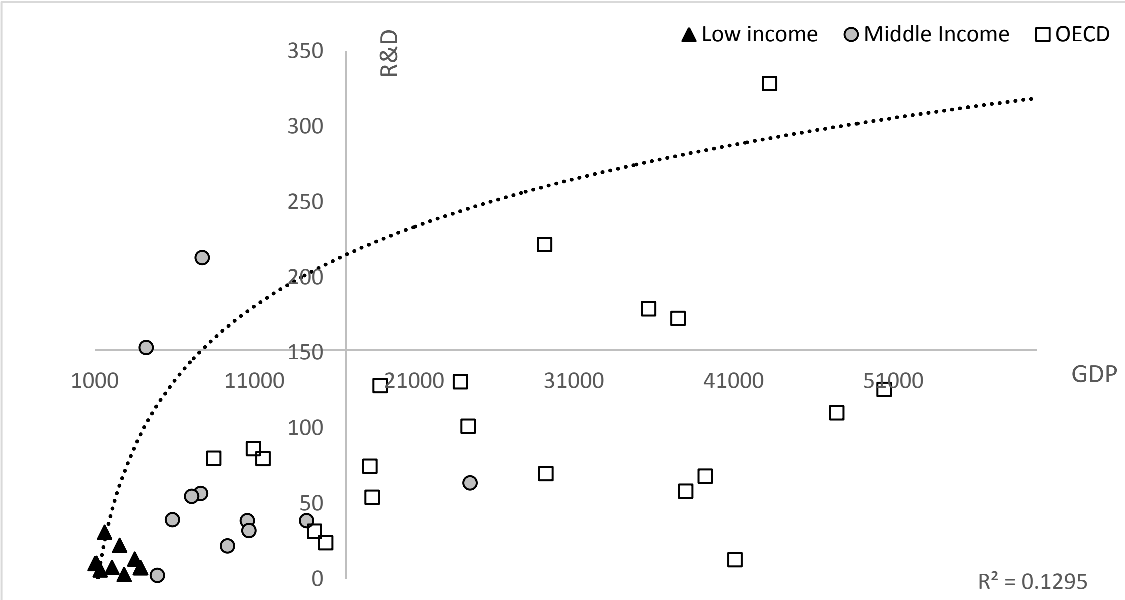


Notes: GDP per capita, constant US$ 2005. GINI index. Obs.: 81. Axes cross each other on average values. Source: own elaboration.

Another element that arises from this relationship is the selection of per capita GDP growth as a proxy of an improvement in the level of development. This variable allows us to measure the evolution of the productive and economic performance of countries, which is a requisite for sustainable development. At the same time, this is a variable used frequently in the innovation system literature, which improves the comparability of our results.

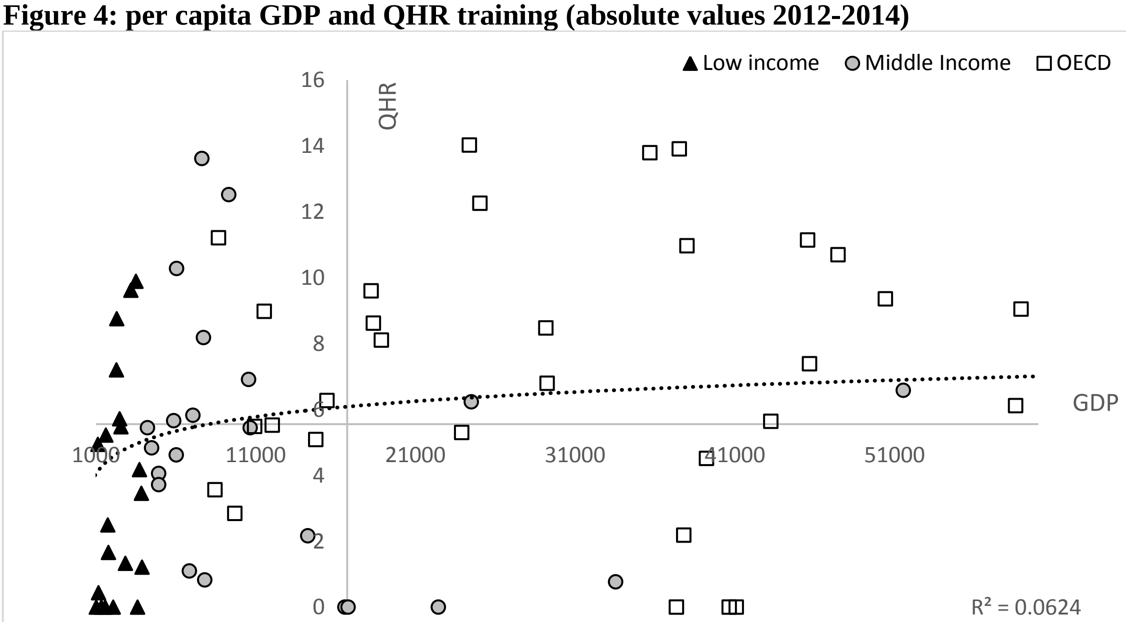
The variables selected to approximate capability investments account for the efforts countries make to increase their technological knowledge and assets (R&D) and the improvement in their skills and absorptive capacities (tertiary education, QHR). Figures 3 and 4 illustrate the relationship between them and per capita GDP. In the case of R&D investments, the relationship is similar to the one observed for the case of GDP and GINI –with also a similar R^2.These differences in the levels of investments lead to assume that a 1% increase in R&D should impact different in each group of countries. Conversely, there is not a clear association between QHR and GDP. However, literature review from section 2 leads to expect differential impacts too.

Figure 3: per capita GDP and R&D investments (absolute values 2012-2014)



Notes: GDP and R&D per capita, constant US$ 2005. Obs.: 81. Axes cross each other on average values. Source: own elaboration.

Figure 4: per capita GDP and QHR training (absolute values 2012-2014)



Notes: GDP per capita, constant US$ 2005. QHR, per thousand persons. Obs.: 81. Axes cross each other on average values. Source: own elaboration.

Table 2 summarizes the variables analysed in the previous paragraphs plus a set of variables related to human development and economic performance, for each group of countries, for the periods 2000-2002 and 2012-2014. According to the values presented there, there are large differences between groups for all variables, which provides a first insight of the usefulness of the categorization to identify different levels of impact. Regarding economic variables and investments in capabilities, OECD countries have a GDP per capita 16 times larger than low income countries, with similar distances in the case of the level gross capital formation. The difference in the level of R&D expenditure is even higher (closer to 20 times) and the relative number of QHR is twice the number of less developed countries. Distances are also significant when OECD and middle income countries are compared, although lower differences are observed in the case of economic variables. In terms of human development, the distance between OECD members and the rest of the countries are also remarkable. For instance, the expectancy of life at birth among people from OECD countries is, on average, 80 years, with a minimum of 74 in 2012-2014, among low income countries the mean value is 69.6 years with a minimum of 49.

Table 2: Selected indicators per development level – Values (standard deviation)

	OECD countries		**Middle income countries**		**Low income countries**	
	2000-02	**2012-14**	**2000-02**	**2012-14**	**2000-02**	**2012-14**
Gross domestic product *(US$ pc.)*	27,761	31,350	11,037	12,912	1,678	1,960
	(15459.51)	(16285.76)	(7612.201)	(11481.3)	(1159.94)	(1176.315)
Gross capital formation *(US$ pc.)*	6,349	6,825	2,013	2,429	384	587
	(3320.649)	(3754.536)	(1343.898)	(1891.082)	(232.475)	(394.9057)
R&D *(PPP pc.)*	487.57	649.10	56.86	117.46	20.36	34.65
	(352.0152)	(407.1108)	(43.97918)	(79.35021)	(22.29467)	(51.52224)
QHR *(000graduates pc)*	6.91	10.17	4.80	8.10	3.82	5.97
	(2.6161)	(3.1511)	(2.4271)	(3.2507)	(2.8975)	(3.7767)
Life expectancy at birth, *(years)*	77.2	80.4	74.6	76.1	66.6	69.5
	(2.77434)	(2.308292)	(3.537711)	(3.428528)	(7.717195)	(6.735204)
Poverty gap at $1.9 a day *(%, PPP)*	0.7	0.3	2.0	2.3	8.5	5.4
	(1.101017)	(0.4047193)	(2.171982)	(5.503404)	(10.89125)	(10.14731)
N	32	30	15	21	33	24

Notes: US$: constant US dollars 2005. PC: per capita. %, PPP: percentage of total population under national poverty line, purchasing power parity. Source: own elaboration.

3.3.2. National innovation systems: key dimensions

National innovation systems can be defined in the narrow or the broad sense (Lundvall, 2007). In the narrow sense, the NIS is made up of the knowledge infrastructure and the firm, usually referred to as the core of the system. The knowledge infrastructure (or knowledge supply) includes universities and S&T institutions, whether they are public or private ones. These institutions constitute one of the axes of the approach: universities in their role of “producers” of skilled human resources and S&T institutions as knowledge creators. In the broad sense, Lundvall (2007) refers to the system as the "wider setting" that surrounds the core of the system. This extended concept includes all those institutions—formal and non-formalized—that affect not only the innovative dynamic but also the process of competence building. These are the labour market, the macroeconomic trajectory, the financial system, the government, the public and private demand, the social dynamics, among others. When it comes to analysing countries with different levels of development, the broad definition is suggested to use since "the rest" of the institutions play a key role in promoting or blocking the innovative process among firms, the creation of knowledge within the S&T systems and the interactions between them (Johnson et al., 2003).

Based on the broad definition of the NIS and given the expected correlation between variables, a principal components factor analysis was estimated and results are presented in table 3. In order to control for the characteristics of the national innovation system, and following the methodology proposed by Srholec and Fagerberg (2008), 29 indicators for the period 2000-2014 were selected to account for the dimensions of the broad system which, according to the evidence, explain the bulk of the heterogeneity between countries[6]. Details of each variable are provided in appendix A. Factor analysis shows 6 relevant factors associated with the different dimensions of innovation systems. The most important component accounts for more than 38% of variability and explains the dimensions of the productive structure. The second relevant component account for the availability of basic infrastructure and education (primary and secondary), the third one refers to the size of the country and the fourth to the equity level. Together, these four dimensions account for nearly 65% of the reported differences between countries. The remaining two components are related to the export profile (10% of variability), one associated with high tech exports and the other one to the share of fuel exports in total external sales.

[6] Fagerberg y Srholec (2008) analyse more than 100 indicators potentially relevant and then reduce them to a set of 25, based on a three-year average, In this paper, a similar approach was followed based on covariates and data availability with the objective of maximize the number of less developed countries in the database.

Table3: Factor analysis – Principal components.

	Productive structure	Basic infrastructure	Size	Equity	High tech exporters	Fuel exporters
General characteristics						
GDP	0.9396	0.2005	-0.0098	0.0928	-0.031	0.0651
Population	-0.0861	-0.0515	0.8798	-0.0021	0.0113	-0.058
Surface	-0.0875	-0.0112	0.7545	-0.3148	-0.1793	0.2207
Private sector						
Gross capital formation	0.9069	0.1909	-0.0231	0.1782	-0.0278	0.0968
Agriculture, value added	0.6661	0.3859	-0.1322	-0.1033	0.1281	0.2178
Manufacture, value-added	0.8974	0.142	0.0219	0.1667	0.0846	0.1659
Exports of goods	0.8875	0.1152	-0.09	0.1863	0.2289	0.0587
Fuel exports	-0.132	0.2325	0.3282	-0.0645	-0.005	0.5674
High-tech exports	0.5456	0.0409	-0.0141	-0.0214	0.6702	0.027
Imports of goods	0.8972	0.136	-0.114	0.2291	0.1684	0.0426
Private credit	0.3172	0.1684	0.1037	-0.1674	0.5315	-0.4254
Interest rate	-0.0177	-0.0264	0.0652	0.0117	-0.6706	-0.0156
Patents	-0.0734	0.15	0.7597	0.2801	0.138	-0.0018
Income and expenditures						
Public consumption	-0.1823	-0.8595	-0.0097	-0.0242	-0.0947	0.0592
Gini	0.1788	0.1672	0.0142	0.8805	-0.0169	-0.0075
Unemployment	0.0414	-0.4293	0.0794	-0.2937	0.3869	0.4021
Poverty gap	-0.1823	-0.8595	-0.0097	-0.0242	-0.0947	0.0592
Education						
Primary	0.1544	0.8553	0.1365	0.0154	-0.0074	0.0485
Secondary	0.3571	0.7633	-0.0078	0.4095	-0.0737	-0.1189
Institutions						
Corruption	0.825	0.0317	-0.0495	-0.0685	-0.024	-0.3857
Government Effectiveness	-0.2522	0.1286	-0.075	-0.4253	-0.039	0.1467
Political stability	0.7287	0.0548	-0.2012	0.2492	0.0137	-0.2338
Rule of law	0.8278	0.074	-0.0376	0.0586	0.0722	-0.4736
Accountability	0.7654	0.0781	0.0216	-0.1632	-0.2915	-0.3466
Homicides	0.0969	-0.5045	0.1197	0.3013	-0.0162	0.0895
Infrastructure						
Electricity	0.2119	0.9083	-0.0081	0.1118	0.0419	0.0235
Internet	0.7429	0.3447	-0.0448	0.0572	0.1819	0.037
Health						
Life expectancy	0.4557	0.6454	-0.093	-0.0488	-0.0026	0.1535
Risk of maternal death	0.4948	0.2328	-0.0927	0.6195	-0.1415	0.0806
Eigenvalue	*11.2016*	*3.40236*	*2.17999*	*1.98126*	*1.49857*	*1.26131*
Cumulative variance	*0.3863*	*0.5036*	*0.5788*	*0.6471*	*0.6988*	*0.7422*

Notes: Pooled sample. Obs.: 285. Standardized values. Variables transformed so as higher values represent better situations. Rotated factor loadings. Period 2000-2014.Definitions and units in Appendix A. Source: own elaboration.

3.4. Model and methodology

The relationship between investments and gross domestic product will be analysed in terms of growth rates, estimated as the annual average variation between subperiods, in natural logarithms, without lags. Of course, how much time take R&D or QHR investments to impact GDP is a matter of discussion but the selection we have done is similar to the one used in the literature and, as it was mention before, it constitutes a first approximation to the phenomenon. The extension of the available information could improve our understanding of the optimal time window and the increase in the number of countries reporting the information will permit more complex models to be constructed, allowing for different lags.

Another element that could bias the results is the possible endogeneity between GDP and investments. In this case, our model assumes that past increases in GDP growth rate do not impact on past investments levels. Although this assumption could be difficult to sustain, the span of years is short enough to expect this relationship not to be verified and similar analyses corroborate it (Coad y Rao, 2011; Fagerberg *et al.*, 2007).

The variables to be analysed are all continuous with none truncated values (growth rates can be positive, cero or negative) then an OLS fix effect regression was selected. Given the existence of unobservable characteristics for each country, which tend to remain the same over large periods (structural and idiosyncratic characteristics), a fixed effects model suits better the nature of the phenomenon to be captured. At the same time, additional tests and robust standards error estimations are provided in order to check the goodness of the results and the existence of omitted variables.

Formally, the model is written as:

$$GDP\_Growth_{ti} = \beta_1 + \beta_2 R\&D\_Growth_{ti} + \beta_3 QHR\_Growth_{ti} + Income_i + NIS_{ti} + \beta_4 Population\ density_{ti} + Region_i + \mu_i \quad (1)$$

$$Income_i = (OECD\ countries; middle\ income\ countries),\ reference\ group: Low\ income\ countries. \quad (5)$$

$$NIS_{it} = \beta_a productive\ structure_{ti} + \beta_b basic\ infrastructure + \beta_c size_{ti} + \beta_d equity_{ti} + \beta_e high\ tech\ exporters_{ti} + \beta_f fuel\ exporters_{ti} \quad (4)$$

The model states that the growth rate of the per capita GDP of the country i in time t (GDP_Growth_{ti}), depends on the growth rate of the investments in research and development ($R\&D\_Growth_{ti}$) and on the training of qualified human resources (QHR_Growth_{ti}).

The variable $Income_i$ refers to the taxonomy based on income levels and includes three dummies: OECD, middle income and low income countries. In order to test the relationship between R&D

and QHR and GDP (H1), the model will be run as presented in equation (1). Then, in order to test the existence of differential impacts depending on the type of NIS (H2), the model will be run for each group of income level.

Three sets of control variables were included. One set accounts for characteristics of the national innovation system (NIS_{ti}) and consists of the six principal components identified in section 3.3: productive structure, basic infrastructure, size, equity, high tech exporters and fuel exporters. Another set control variables consists of dummy variables to control for the geographical localization ($region_i$). The regions, which of course are time invariant, are: Asia, Africa, Latin America and the Caribbean, East Europe, West Europe and North America. Finally, the population density ($Population\_density_{ti}$) of countries was included, estimated as the ratio between population and surface in square kilometers, measured as annual average for each subperiod. This is a time variant variable since the nominator changes over time, although with small variations within the period under analysis. Table 4 summarizes the characteristics of each variable.

Table 4: Summary of the variables

Label	Detail	Calculation	Value
Dependent variable			
GDP_Growth_{ti}	Growth rate of gross domestic product.	Annual average rate, per capita, in natural log.	$-\infty - +\infty$
Independent variables			
$R\&D\_Growth_{ti}$	Growth rate of research and development expenditure.	Annual average rate, per capita, in natural log.	$-\infty - +\infty$
QHR_Growth_{ti}	Growth rate of graduated persons in a tertiary degree.	Annual average rate, per capita, in natural log.	$-\infty - +\infty$
$Income_i$	Income-base taxonomy.	OECD, middle-income and low-income countries.	3 dummies
NIS_{it}	National innovation system dimensions.	Six variables: productive structure, basic infrastructure, size, equity, high tech exporters and fuel exporters.	$-\infty - +\infty$
$Population\_density_{ti}$	Total population to total surface.	Average value, people per square kilometre.	0-∞
$Region_i$	Geographical region	One dummy for each region: Asia, Africa, Latin America and the Caribbean, East Europe, West Europe and North America.	6 dummies
β_0	Constant term		
μ_i	Statistical error		
References			
i	Country		1-81
t	Time	t0=2000-02; t1=2003-05; t2=2006-08; t3=2009-11; t4=2012-14	5

A summary of the statistical characteristics of the variables is presented in appendix B.

4. Results

Table 5 presents the results of the estimation for the whole sample. In order to check the robustness of the results, a polled OLS model was run first, and two fixed effect models were estimated afterwards. In the three estimations, a significant correlation between R&D and QHR and GDP is observed. These results verify H1.a and H1.b: a 1% increase in the R&D and QHR growth rate leads to a 0,080% and a 0.077% increase in the GDP growth rate in FE I and II models, respectively. Not surprisingly, the level of equity of the country positively impact on GDP growth, an aspect that is frequently highlight in the NIS literature (Johnson *et al.*, 2003).

Table5: Estimation results – total panel – Dep. var.: GDP growth

	Pooled OLS		**Fix effects (I)**		**Fix effects (II)**	
	Coeff.	SE.	Coeff.	SE	Coeff.	SE
$R\&D\_Growth_{ti}$	0.071***	0.021	0.080**	0.010	0.077**	0.031
QHR_Growth_{ti}	0.010*	0.008	0.081**	0.001	0.082**	0.022
NIS_{it}						
$productive\ structure_{ti}$	0.010	0.011			0.011	0.052
$basic\ infrastructure_{ti}$	0.000	0.000			0.000***	0.000
$size_{ti}$	0.012***	0.004			0.036	0.029
$equity_{ti}$	-0.017*	0.009			0.049*	0.028
$hight\ tech\ exporters_{ti}$	0.000	0.001			0.001	0.000
$fuel\ exporters_{ti}$	-0.003	0.003			-0.017	0.011
$Populationdensity_{ti}$	0.000*	0.000	0.000**	0.000	0.000	0.000
β_0	-0.044**	0.011	-2.11***	0.586	-1.520***	0.567
$Income_i$	*yes*		*yes*		*yes*	
$Region_i$	*yes*		*yes*		*yes*	
t_i	*yes*		*yes*		*yes*	
R^2	0.602		0.552		0.583	

Notes: ***, ** y *: significant at 99%, 95%, & 90%, respectively. Obs.: 285. Pooled OLS includes initial condition. FE includes level controls. Robust standard errors. Source: own elaboration.

Table 6 displays the estimation for the three income levels. The first observation is that R&D and QHR investments do not impact on GDP growth among low income countries. Fort the other two groups, the impact of investments on R&D and training of QHR on GDP growth is positive and significant, and increases together with the income level. Among middle income countries, a 1% increase in R&D and QHR leads to a 0.06% and 0.12% increase in the level of GDP growth. Among OECD countries, these percentages climb up to 0.09% in the case of R&D investments and 0.14% in the case of investments in QHR training. These results confirm H2 for the case of the two upper categories in the sense of a positive relationship between the level of development and the impact of investments on growth. However, investments in R&D and QHR do not impact on the level of GDP growth among low-income countries, which provides evidence regarding the existence of thresholds in the positive relationship between these capabilities and growth. Results also lead to reject H1 in the sense that these investments do not impact on growth in all countries.

The existence of thresholds can also be identified when looking at the actual levels of investments, presented in section 3.1.1. While among OECD countries the expenditure per capita on R&D in 2014 was on average US$650 per year and among middle income countries it was US$118, the average level among low income ones was US$ 34.Differences are lower although still significant for the case of QHR, where levels are 17, 8 and 6 skilled persons per a thousand people in OECD, middle and low income countries, respectively.

Regarding the impact of the NIS dimensions, an interesting result is the significant and positive impact of the basic infrastructure and negative sign of the fuel exporter dimension, among OECD countries. The impact of size among middle income countries is the expected one, to the extent that larger countries in Latin America are more advanced in terms of economic development than small ones in the same region. Population density impact positively and significantly on growth in all countries, although the scale of measuring leads to a very low coefficient.

Table 6: Regression MCO – Dep. var.: GDP growth

	OECD		Middle income		Low income	
	Coeff.	SE	Coeff.	SE	Coeff.	SE
$R\&D\_Growth_{ti}$	0.09**	0.043	0.06*	0.038	0.044	0.036
QHR_Growth_{ti}	0.14***	0.043	0.12**	0.055	-0.01	0.047
NIS_{it}						
$productive\ structure_{ti}$	-0.023	0.066	0.161	0.182	-0.029	0.161
$basic\ infrastructure_{ti}$	0.001**	0.001	0.003	0.003	0.000	0.000
$size_{ti}$	-0.014	0.062	0.732***	0.125	-0.021	0.037
$equity_{ti}$	0.030	0.042	-0.061	0.066	0.025	0.056
$hight\ tech\ exporters_{ti}$	0.000	0.001	0.001	0.001	-0.002	0.002
$fuel\ exporters_{ti}$	-0.024**	0.010	0.017	0.014	0.018**	0.020
$Populationdensity_{ti}$	0.00***	0.001	0.00***	0.000	0.004***	0.001
β_0	-3.95***	1.150	-2.36**	1.179	-2.003**	0.914
$Region_i$	*yes*		*yes*		*yes*	
t_i	*yes*		*yes*		*yes*	
R^2	0.807		0.836		0.568	
N	31		21		30	
Obs.	115		68		92	

Notes: ***, ** y *: significant at 99%, 95%, & 90%, respectively. Robust standard errors. Within R^2. Level controls included. Source: own elaboration.

From an aggregated perspective, results agree with the NIS literature to the extent that the process of knowledge creation and diffusion into innovations depends on the characteristics of the national innovation system. In this respect, R&D and QHR will impact different since each system has particular sets of organizations and capabilities to absorbed and apply knowledge. Among low income countries, results agree with the literature about the existence of countries lagging behind in the growth race (Cimoli, 2014; Verspagen, 1991). Within this literature, there is not a process of catch up, all of the contrary, countries are trapped into a process of underdevelopment. The lack of organizations, institutions and capabilities seems to be the explanation of the absence of impact among low income countries. Within these systems, and in line with the empirical evidence, reaching a sustainable growth path depends on the development of basic capabilities such as primary and secondary education and basic productive skills (Lee, 2013b; Lee y Kim, 2009b). Then, investments in R&D and the training of QHR should be articulated with that.

Regarding middle income countries, evidence leads to assume that there is not a rate of R&D and QHR growth that automatically leads to catch up. Conversely, results highlight the need to complements investments with changes in other dimensions of the national innovation system. In this respect, results agree with studies about the need of coevolution between capabilities – absorptive, productive, innovative, etc. (Castellacci y Natera, 2013; Natera, 2016). In this respect, results would be closer to the literature about the existence of convergence clubs (Castellacci, 2008; Castellacci y Archibugi, 2008) to the extent that higher levels of investments or training will lead to higher levels of GDP growth without altering the development path. To modify the process, changes in the national system are required. In other words, it is about developing the national innovation system.

Once again, these results should not be read in terms of who should make R&D and train QHR and who should not. Our results points to the need developing countries to invest and R&D and train QHR together with changes in the productive structure, the institutional set up and the knowledge and fiscal infrastructure, to the extent that these are complementary investments. The challenge is to transform the system in a way that it demands and produces higher capabilities and technological complexity. Evidence about catch up seems to point that way (Lee, 2013a; Molina y Urraca Ruiz, 2014).

Finally, a dimension not explored here but interesting for future research is the fact that R&D investments and QHR training are treated as homogeneous variables, and the relevant measure is their relationship with the level of GDP. Evidence seems to indicate the existence of heterogeneity within these activities. If countries have different specificities that impact their path of growth and development, activities oriented to create basic and applied knowledge and to develop absorptive and innovative capabilities should be articulated with those specificities to maximize their impact. The other way around, evidence also points to the existence of specificities that block development (e.g.: the specialization pattern), in those cases, the question is how to promote specific sets of R&D activities and QHR personal that help to unlock the process. In other words, the need to move forward into a national innovation system for development.

5. Conclusions

The objective of this paper was to analyse the relationship between investments in R&D and QHR training and GDP in order to test the convergence and the specificities hypotheses. The theoretical and conceptual discussion of the first hypothesis showed the scarce attention paid to the technological, structural and regional determinants of growth and development. We claim that the development of productive structures and innovation processes in less developed countries depends on the ability of these economies to move into more complex processes of generation, application and dissemination of knowledge, which can also be achieved if they move from to a more complex national innovation system. This requires the development of absorptive and innovation capabilities, the improvement and creation of key institutions and the upgrading of the productive structure. In the long run, development is about setting in motion processes of structural change aimed at increasing diversification, integration and dissemination of innovations.

Regarding investments in capabilities, the analysis showed that their impact on growth and development depends on the characteristics of the NIS where they are allocated. Moreover, results show that for those less developed countries, investments in R&D and QHR do not impact directly on GDP. In the case of middle income countries, results show that investments impact lower than among OECD countries which accounts for the fact that investments in R&D and QHR have to be part of a more systemic process of development of the NIS. The productive environment, the institutional set up and even the levels of equity determines how capabilities are transformed into economic growth and eventually, development. Therefore, middle income nations, especially Latin American countries, are trapped in the middle not just because of the level of their R&D efforts and QHR training but because of the characteristics of those investments. They are trapped into a low-development situation because the lack of a systemic (articulated) process of the system that surround the investments, the scarce linkages among the productive and institutional components of the NIS and how investments and the productive and social dynamics interact.

In this regard, this paper has tended to contribute to opening the black box of development. The fact that equal inputs leads to different outputs accounts for the existence of specific national dynamics. We claim that it is about understanding the specific, cumulative and path-dependence dynamics of development and how the application of knowledge -innovations- triggers a sustainable and inclusive process of growth. The 2008 international financial crisis and the deep recession in southern Europe have shown that development is not just about increasing levels of R&D, the share of high tech industries, or the number of patents. This recent history has highlighted the need to question the assumptions we have made if we want to understand the process of development.

Of course, this is a preliminary analysis with limitations, especially referred to the amount of available information for developing countries and the variables we selected –e.g. future research could go deeper into the interaction between public and private investments. First, this research has shown that increase the level of R&D and QHR positively contributes to GDP growth among high and medium income countries, which implies that science, technology and education play a key role in development. This rejects the idea that frontier investments are a matter of developed countries. Results also provide evidence regarding the existence of thresholds and the need to continue improving absolute levels. In this regard, results indicate that once countries reach a minimum level of investment, R&D activities have increasing returns. Thus, while low-income countries face the (huge) challenge of implementing processes of technological complexity that allow them overcome that threshold, the middle-income countries must overcome the second threshold and significantly increase the relative level of investments to close the gap with high-income countries together with changes in the system. Of course, this cannot be achieved only via increases in the level of R&D or QHR; scale changes like those observed for each income level require a general improvement in the process of creation and appropriation of knowledge, that is to say, the development of a national innovation system.

Appendix A

A. Data

A.1. Variables, scaling and sources

	Definition	**Scaling**	**Source**
General characteristics			
GDP	Gross domestic product	US$ 2005, per capita	WDI-WB
Population	Total population, number	Persons	WDI-WB
Surface	Territory	Square kilometres	WDI-WB
Private sector			
Gross capital formation	Gross capital formation	US$ 2005, per capita	WDI-WB
Agriculture, value added	Agriculture, value added	US$ 2005, per capita	WDI-WB
Manufacture, value added	Manufacture, value added	US$ 2005, per capita	WDI-WB
Exports of goods	Exports of goods and services	US$ 2005, per capita	WDI-WB
Fuel exports	Fuel exports	% total merchandise exports	WDI-WB
High-tech exports	Exports of high-tech goods and services	U$S	WDI-WB
Imports of goods	Imports of goods and services	US$ 2005, per capita	WDI-WB
Private credit	Domestic credit to private sector	% GDP	WDI-WB
Interest rate	Real interest rate*	%	WDI-WB
Patents	Patent applications, residents	Number	WDI-WB
Income and expenditures			
Public consumption	General government final consumption expenditure	US$ 2005, per capita	WDI-WB
GINI	GINI index, World Bank estimate*	Index	WDI-WB
Unemployment	Total unemployment, national estimate*	% total labour force	WDI-WB
Poverty gap	Poverty gap at $1.90 a day*	% poverty line	WDI-WB
Education			
Primary	Primary completion rate	% relevant age group	WDI-WB
Secondary	Secondary school enrolment	% net	WDI-WB
Institutions			
Corruption	Control of corruption	Index	WGI - WB
Government Effectiveness	Government effectiveness	Index	WGI - WB
Political stability	Political stability and absence of violence/terrorism	Index	WGI - WB
Rule of law	Rule of law	Index	WGI - WB
Accountability	Voice and accountability	Index	WGI - WB
Homicides	Intentional homicides*	Per 100,000 people	WDI-WB
Infrastructure			
Electricity	Access to electricity	% population	WDI-WB
Internet	Internet users	Per 100 people	WDI-WB
Health			
Life expectancy	Life expectancy at birth	Years	WDI-WB
Risk of maternal death	Lifetime risk of maternal death*	Persons	WDI-WB
Investments in capabilities			
R&D	Gross domestic expenditure on research and development	US$ 2005, per capita	UIS - UNESCO
QHR	Graduates from tertiary education	Number of persons per capita	UIS - UNESCO

Notes: WDI-WB: World development indicators, World Bank database. UIS-UNESCO: UNESCO institute for statistics, UNESCO database. WGI-BM: World governance indicators, World Bank database. * Inverse values (1/variable).

A.2. Countries, regions and income classification

Country	Region	Income	Country	Region	Income	Country	Region	Income
Argentina	LAC	MI	Honduras	LAC	LI	Mozambique	AF	LI
Armenia	AF	LI	Hong Kong	AS	MI	Netherlands	EUNA	OECD
Australia	AS	OECD	Hungary	EUNA	OECD	New Zealand	AS	OECD
Austria	EUNA	OECD	Iceland	RE	OECD	Norway	RE	OECD
Belarus	RE	MI	India	AS	LI	Panama	LAC	MI
Belgium	EUNA	OECD	Indonesia	AS	LI	Philippines	AS	LI
Bolivia	LAC	LI	Iran	AS	LI	Poland	EUNA	OECD
Brazil	LAC	MI	Ireland	EUNA	OECD	Portugal	EUNA	OECD
Brunei Darussalam	AS	MI	Israel	AS	OECD	Romania	EUNA	MI
Bulgaria	EUNA	MI	Italy	EUNA	OECD	Russia	RE	MI
Canada	EUNA	OECD	Japan	AS	OECD	Saudi Arabia	AF	MI
Chile	LAC	OECD	Jordan	AF	LI	Serbia	RE	MI
China	AS	LI	Korea, Rep.	AS	OECD	Slovakia	EUNA	OECD
Colombia	LAC	MI	Kyrgyzstan	AS	LI	Slovenia	EUNA	OECD
Costa Rica	LAC	MI	Latvia	EUNA	MI	Spain	EUNA	OECD
Croatia	EUNA	MI	Lesotho	AF	LI	Sweden	EUNA	OECD
Cyprus	EUNA	MI	Lithuania	EUNA	MI	Switzerland	RE	OECD
Czech Republic	EUNA	OECD	Luxemburg	EUNA	OECD	Thailand	AS	LI
Denmark	EUNA	OECD	Macao	AS	MI	Trinidad and Tobago	LAC	MI
El Salvador	LAC	LI	Macedonia	RE	LI	Tunisia	AF	LI
Estonia	EUNA	OECD	Madagascar	AF	LI	Turkey	RE	OECD
Ethiopia	AF	LI	Malaysia	AS	MI	Uganda	AF	LI
Finland	EUNA	OECD	Malta	AF	MI	Ukraine	RE	LI
France	EUNA	OECD	Mexico	LAC	OECD	United Kingdom	EUNA	OECD
Georgia	RE	LI	Moldova	RE	LI	United States	EUNA	OECD
Greece	EUNA	OECD	Mongolia	AS	LI	Uruguay	LAC	MI
Guatemala	LAC	LI	Morocco	AF	LI	Vietnam	AS	LI

Notes: Subperiod: 2012-2014. LAC: Latin America and the Caribbean; AF: Africa; AS: Asia and the Pacific; EUNA: European Union and North America; RE: rest of Europe. OECD: OECD member countries; MI: middle income countries; LI: low income countries.

B. Descriptive statistics

B.1. Covariates matrix

	GDP growth	R&D growth	QHR growth	Productive structure	Basic infras.	Size	Equity	High tech exp.	Fuel exporters	Pop. density
GDP growth	1									
R&D growth	0.342*	1								
QHR growth	-0.031	-0.027	1							
Productive structure	-0.367*	-0.172*	0.077*	1						
Basic infras.	0.049*	-0.027	-0.002	-0.046*	1					
Size	0.114*	0.060*	0.080*	0.104*	0.009	1				
Equity	-0.139*	-0.157*	0.059*	-0.025	-0.124*	-0.024	1			
High tech exp.	-0.079*	-0.018	0.001	0.212*	-0.005	0.122*	-0.173*	1		
Fuel exporters	-0.095*	-0.039	0.051*	0.052*	-0.080*	0.023	0.039*	-0.093*	1	
Pop. density	0.254*	0.052*	-0.013	0.133*	-0.01	-0.065*	-0.102*	0.106*	-0.072*	1

Notes: pooled sample. Obs.: 285. * Significant at 95%. Source: own elaboration.

B.2. GDP, R&D and QHR – Absolute values (standard deviation)

	OECD countries		Middle income countries		Low income countries	
	2000-02	**2003-2005**	**2000-02**	**2003-2005**	**2000-02**	**2003-2005**
Gross domestic product	27761	29150	11037	11085	1678	1666
(US$ pc.)	(15459.51)	(16204.28)	(7612.201)	(8055.96)	(1159.94)	(1074.70)
Gross capital formation	6349	6866	2013	2197	384	444
(US$ pc.)	(3320.65)	(3655.20)	(1343.90)	(1438.59)	(232.47)	(283.61)
R&D	487.57	513.22	56.86	72.55	20.36	20.62
(US$ pc.)	(352.01)	(364.63)	(43.98)	(58.71)	(22.29)	(22.53)
QHR	6.91	22.07	4.80	6.47	3.82	4.24
(000graduates pc)	(2.61)	(79.33)	(2.4)	(3.869)	(2.90)	(3.29)
Life expectancy at birth,	77.20	77.99	74.60	74.42	66.60	67.10
(years)	(2.77)	(2.70)	(3.54)	(3.99)	(7.72)	(7.77)
Poverty gap at $1.9 a day	0.70	0.55	2.00	1.83	8.50	6.27
(%, population)	(1.10)	(0.90)	(2.17)	(1.77)	(10.89)	(8.92)
N	32	32	15	18	33	30
	OECD countries		**Middle income countries**		**Low income countries**	
	2006-2008	**2009-2011**	**2006-2008**	**2009-2011**	**2006-2008**	**2009-2011**
Gross domestic product	31578	1956	12444	12599	1887	1956
(US$ pc.)	(16790.27)	(1237.43)	(8992.70)	(9837.48)	(1204.80)	(1237.43)
Gross capital formation	7923	548	2849	2377	567	548
(US$ pc.)	(4247.37)	(375.59)	(2263.19)	(1633.81)	(370.96)	(375.59)
R&D	590.2536	25.19833	88.43161	103.3942	24.79964	25.19833
(US$ pc.)	(394.29)	(32.17)	(70.44)	(72.97)	(28.88)	(32.17)
QHR	8.6504	6.2775	7.1847	8.3322	5.0029	6.2775
(000graduates pc)	(2.79)	(4.87)	(3.58)	(3.91)	(3.83)	(4.87)
Life expectancy at birth,	78.88363	68.93437	74.84582	75.44804	67.91464	68.93437
(years)	(2.64)	(7.02)	(3.83)	(3.71)	(7.43)	(7.02)
Poverty gap at $1.9 a day	0.3178689	5.869624	1.250453	1.158995	5.523125	5.869624
(%, population)	(0.31)	(10.25)	(1.11)	(1.61)	(8.85)	(10.26)
N	30	30	19	19	29	26
	OECD countries		**Middle income countries**		**Low income countries**	
	2012-14	**Total**	**2012-14**	**Total**	**2012-14**	**Total**
Gross domestic product	31350	30197	12912	12102	1,960	1820
(US$ pc.)	(16285.76)	(16057.91)	(11481.3)	(9294.65)	(1176.31)	(1161.67)
Gross capital formation	6825	6943	2429	2391	587	501
(US$ pc.)	(3754.54)	(3711.13)	(1891.08)	(1747.51)	(394.91)	(338.03)
R&D	649.1	568.241	117.46	89.28093	34.65	23.84761
(US$ pc.)	(407.11)	(381.32)	(79.35)	(69.01)	(51.52)	(29.85)
QHR	10.17	8.5913	8.1	7.1016	5.97	4.965
(000graduates pc)	(3.15)	(3.09)	(3.25)	(3.62)	(3.78)	(3.81)
Life expectancy at birth,	80.4	78.83203	76.1	75.13665	69.5	67.93757
(years)	(2.31)	(2.80)	(3.43)	(3.67)	(6.74)	(7.35)
Poverty gap at $1.9 a day	0.3	0.4262537	2.3	1.687629	5.4	6.364505
(%, population)	(0.40)	(0.65)	(5.50)	(3.04)	(10.14)	(9.77)
N	30	160	21	94	24	146

Notes: US$: constant US dollars 2005. PC: per capita. %, PPP: percentage of total population under national poverty line, purchasing power parity. Source: own elaboration.

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