Role of Human Resources in the Promotion of Technological Innovation in Emerging and Developing Countries

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Summary:

This study examines the impact of human resources on technological innovation in emerging and developing countries. The overview of previous literature allows us to assume that human resources influence innovation via two channels: direct and indirect through their interaction with foreign knowledge sources. The sample used to test our hypotheses is a panel of 15 countries over the period 2000-2010. Results of the estimation of linear regression models show that human capital affects positively and directly innovation. However, the indirect effect is not significant. We conclude that the promotion of human resources is an effective direct tool of public innovation policy.

Key words: R&D specific human capital, general human capital, technology importation, innovation , emerging and developing countries.

JEL Classification: O3.

1. Introduction

Positive economic growth is enabled by the positive growth of human capital stock, which in turn boosts a country's ability to innovate. The accumulation of human capital is essential for innovation and in turn it drives the countries' technological change level (Nelson and Phelps, 1966; Romer, 1990). Human capital and skilled labour complement technological advances: new technologies cannot be adopted in production without the sufficient training and education of the workforce. The demand side is also important, as innovation may not occur if demanding customers and consumers are lacking. The countries that able to coordinate policies for education, skills development, and innovation are certainly better positioned to compete in the global economic environment. Indeed, a number of countries are now seeking to do this.

Previous studies on the relationship between human capital and innovation can be classified into two categories: Those whose research topic focuses on firms (Gimeno et al., 1997; Van Uden et al., 2014; Smith et al., 2005; Schneider et al., 2010; Knight et al., 2003) and those whose research topic focuses on the countries (Benhabib and Spiegel, 1994; Hall and Jones, 1999; Dakhli and De Clercq, 2004; Ulku, 2007; Miguélez et al., 2011).

This paper is intended to enrich the existing literature at country level, by focusing on Emerging and Developing Countries[1] (EDC). The research question

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[1] In this paper, we adopt the ranking of countries according to the report of the International Monetary Fund (IMF, 2012), which classifies countries into two categories: "Advanced Economies" and "Emerging and Developing Economies."

to be examined is as follows: What's the effect of human resources on technological innovation in emerging and developing countries?

To answer this question, we will estimate a linear regression model on a sample of 15 countries over the period 2000-2010.

In the following, section 1 presents theoretical background. Section 2 reviews the literature. Section 3 discusses the methodology. Finally, section 4 presents the results.

2. Theoretical background

The OECD (2001, p.18) defines human capital as "The knowledge, skills, and attributes embodied in competencies individuals that facilitate the establishment of personal, social and economic well-being."

Schumpeter was the first to explain the emergence of innovations focusing on the importance of entrepreneurial efforts. This documents the importance of individual capabilities.

Going further, the systemic innovation theory teaches us that today innovation is an interactive process that largely involves inter-personal as well as inter-organisational learning (Kline and Rosenberg, 1986). Lundvall states that there are two ways in which higher education has an impact on innovation: On the one hand, higher education graduates can operate as basic innovators, for instance, by inventing and developing new technologies. On the other hand, they might serve as second stage innovators, who rather exploit technological progress and ensure the equilibrium between technological change and daily business. According to this differentiation, he concludes that engineers and scientists are particularly active as basic innovators while people with a management or social sciences degree are important as second stage innovators (Lundvall, 2007).

The initiation of human capital theory by Schultz (1961) and Becker (1964 cited in Dakhli and De Clercq, 2004) led to the inclusion of human capital.

The study of the interaction between human capital and technological change begins with seminal contribution of Nelson and Phelps (1966). They have found a strong link between technical progress and education. Their first conclusion is that productivity and innovation growth rates are positively correlated with the level of education, especially with the number of people with a higher level of education or university degrees. They also showed that different levels of human capital determine the differences between countries in technology adopted and used. Most of the Asian developing countries have witnessed a 'miracle' of transformational economic growth. For example, Taiwan, Hong Kong, and Singapore have become key exporters of a sophisticated range of products. This rapid progress is attributed to, among other factors, the fast growth rate of human capital accumulation and the attainment of new capabilities.

Furthermore, the model of Lucas (1988) states that investment in human capital generates positive externalities that improve the productivity of the economic system and increase its growth rate.

The new growth theories are considered the most significant to explain innovation and economic growth at the macro level by the human capital factor (Aghion and Howitt, 1998).

According to the first generation of endogenous growth models of Romer (1986, 1990), Grossman and Helpman (1991) and Aghion and Howitt (1992), endogenous technological change explains the growth rate of production in the long term. The main assumptions of these models are (i) Technological innovation is determined by the stock of knowledge and human capital engaged in R&D and (ii) Innovation has a unit elasticity with respect to both inputs.

According to these models, the aggregate production is described by the following Cobb-Douglas function:

$$Y(t) = A(t)\, X(t)^{\alpha} H_Y(t)^{\beta} L_Y(t)^{1-\alpha-\beta} \qquad (1)$$

Y, A, X, H_Y and L_Y are respectively the final output, technological innovation, physical capital, human capital and labour used in the final output sector.

Technological innovation is created according to the following functional form:

$$\dot{A}(t) = A(t)\lambda H_A(t) \qquad (2)$$

Where A is the stock of knowledge, and H_A is the human capital employed in the R&D sector. However, the assumption that innovation has a unit elasticity with respect to human capital in the R&D sector implies a scale effect: The growth rate of long-term production is determined by the level of the population. This hypothesis was rejected by Jones (1995), who concluded that there was no relationship between total factor productivity and the number of scientists and engineers in France, Germany, Japan and the United States.

The second generation of endogenous growth models of Young (1998), Aghion and Howitt (1998) and Dinopoulos and Thompson (2000) has removed the scale effect of previous models. These economists point out that the increase in population increases not only the investment of R&D and human capital, but also the number of new products and sectors. So, additional investment in R&D and additional human capital resulting from an increase of the population are absorbed by the new sectors. Consequently, the share of R&D of each sector remains the same. Thus, they suggest that it is the share of R&D investments in the total economy or the share of researchers in the population that should be used for testing R&D models, rather than the absolute value of R&D investments and the absolute number of researchers.

A modified version of equation (2) is given by Dinopoulos and Thompson (2000). It takes the following form:

$$\dot{A}(t) = A(t)^{\Phi}\gamma \left(\frac{H_A(t)}{L(t)}\right)^{\psi} \quad \Phi = 1, \qquad (3)$$

Where $\dot{A}$, A, H and L are respectively technological innovation, the stock of knowledge, human capital in the R&D sector and the labour force, ψ measures the returns to scale in knowledge creation, and γ is equal to $\lambda / k^{\psi} > 0$, k is a constant.

3. Overview of Literature

3.1 Skills required for innovation in Emerging and Developing Countries

In the context of emerging and developing countries, a context of technological catch-up, the innovation depends critically on links with the rest of the world. The technology acquisition in follower countries depends on the technology transfer. However, the access to foreign technology is not equivalent to its effective use. Although the equipment and technology models can be imported from developed countries, the ability to make effective use of these elements can not be transferred in the same way. These abilities are acquired only by a local learning process. This is because knowledge has tacit elements, and because it is often necessary to adapt foreign technologies to local conditions.

The imitation of advanced technology is a learning process that is essential for the catching of laggards, as at an early stage, future technological development is based on external knowledge. Yet, the passive imitation of the existing knowledge is not enough to successful and long term technological catch-up. In the first phase of upgrading, latecomers receive obsolete technology from leading countries. However, when they reach a certain technological level, most holders are reluctant to transfer new technologies. Active innovation through own research and development is therefore crucial for technological catching-up (Kim, 1980; Lee et al., 1988).

Thus, technological innovation in the context of EDC is a learning process including adoption and adaptation of existing technologies and creation of new technologies.

Previous work showed that innovation requires managerial and communication skills in addition to a scientific supply and well trained engineers. The ability to innovate will increasingly require individuals to be able to understand the nature of problems and to have the aptitude and creativity to address them. Research and Development (R&D) is only the tip of the technology development and innovation process, which includes, in addition, such non-R&D activities as the skills for acquiring, using, and operating technologies at rising levels of complexity, productivity, and quality; and the design, engineering, and associated managerial capabilities for acquiring technologies, developing a continuous stream of improvements, and generating innovations. According to the World Bank (2010), general skills become more useful than specialization (specific human capital for R&D).

3.2 The impact of human capital on innovation in emerging and developing countries

Human capital influences the innovation of EDC in two main ways: On the one hand it allows the generation of new knowledge. On the other hand, it enables the adoption and adaptation of existing ideas.

The generation of new knowledge

The well-qualified people generate knowledge that can be used to create and introduce innovation. Jaumotte and Pain (2005) show that differences between countries in the share of scientists and engineers in total employment cause significant differences between countries in R&D performed by the business sector.

The empirical work of Furman et al. (2002) confirms that differences in national innovation activities measured by the number of patents per capita are attributable to differences in the number of scientists and engineers employed. Ulku (2007) uses data from 41 OECD and non OECD countries to examine the predictions of non-scale endogenous growth theories that an increase in the share of researchers in labour force leads to an increase in innovation and innovation raises per capita output. The results show that an increase in the share of researchers in labour force increases innovation only in the large market OECD countries.

At company level, Caloghirou et al. (2004) used data from a survey for 7 European countries: Greece, Italy, Denmark, UK, France, Germany and the Netherlands, during the period from February to June 2000. The results from their estimations show a strong positive relationship between the extent of innovation of the firms and their R&D intensity and personnel qualifications, whereas the human resources training factor is not significant in this relationship.

Van Uden et al. (2014) examine whether human capital endowments of firms and practices of firms, such as formal training and employee slack time, have a positive relation with the innovative output of firms in developing countries (Kenya, Tanzania and Uganda). The results show a positive relation between human capital and innovation. In particular, the role of practices of firms such as offering formal training and employee slack time are conducive to innovative output.

In view of these arguments, we predict:

Hypothesis 1: The general and specific human capital in R&D activity directly stimulates technological innovation.

The adoption and adaptation of existing ideas

In EDC, incremental innovations involving changes and improvements to the existing products and processes, are an important part of innovation activities and have a great importance for the productivity and quality of goods and services. High skill levels increase the ability to perform incremental innovation by allowing individuals to better understand how the technologies work and how they can be improved or applied to other areas of the economy.

Eaton and Kortum (1996) suggest that the diffusion of technology increases with the level of human capital of a country. Griffith et al. (2004) examined the determinants of productivity growth in 12 OECD countries. They found that skills of labour force help boost productivity growth through their effects on innovation (direct effect) and by facilitating the adoption and diffusion of new technologies (an indirect effect) that enable countries to catch up with global technology leaders.

Furthermore, empirical studies on procurement strategies show that the internal R&D and purchase of external technology are two complementary strategies. Based on the concept of absorption capacity proposed by Cohen and Levinthal (1990), these studies emphasize that the successful use of external technology requires the ability to assimilate and apply it internally. Teixeira and Fortuna (2010) note that import technologies drive productivity only if the economy reaches a sufficiently high level of education or local R&D effort that can enable the efficient use of imported technology. Liu and White (1997) found that in the Chinese companies, innovation measured by the share of new products'sales in the total sales is generated through the synergy between the investment in the R&D personnel and foreign technology rather than rely only on one or the other input.

Moreover, Fu et al. (2010) argue that the absorptive capacity level is a prerequisite for an efficient transfer of technology to developing countries. In this sense, the parallel efforts of indigenous innovation are complementary with international technology diffusion. The latter has not an automatic and direct effect on the level of innovation. It requires the recipient to have sufficient capacity to absorb and adopt such technology. Therefore important interactions must exist between foreign sources of knowledge and local R&D efforts.

Thus we predict :

Hypothesis 2 : The specific human capital to R&D activity stimulates indirectly technological innovation through its interaction with foreign sources of knowledge.

3.3 Control variables

Besides human capital, endogenous growth theory emphasizes the role of the stock of knowledge in technological innovation. The latter is also influenced by many other social and economic variables. We choose three variables that we consider interesting in the context of our research, namely: the institutional framework, the size of the population and imports of high technologies.

The knowledge stock is an important determinant of productivity. Coe and Helpman (1995) point out that on the one hand, innovation is based on knowledge and on the other hand, it contributes to the stock of knowledge. Porter and Stern (2000), Furman et al. (2002), Schneider (2005) and Teixeira and Fortuna (2010) found a significant positive impact of the knowledge stock on technological innovation.

Sala-i-Martin (2002) argues that it is difficult to find new and better technologies if an economy does not have good institutions. Mahagaonkar (2008) shows a negative relationship between corruption and innovation. Tebaldi and Elmslie (2013) confirmed a positive link between the quality of economic institutions and innovation.

Pritchett (1996) recognizes four reasons why a large population could be useful. First, the pressure of high population can induce changes that lead to greater productivity. Second, economic growth theories assume that knowledge is a non-rival. This implies that once the innovation is created, a number of people can use it to create others. More important is the number, the wider the use and exploitation, and therefore the creation of innovations. Third, a larger population can lead to greater production through economies of scale. Finally, even in the absence of economies of scale, greater population can lead to agglomeration economies. Lerner (2002), Furman et al. (2002) and Chen and Puttitanun (2005) found a positive impact of country size on technological innovation.

Imports of foreign technology can improve the technological knowledge in emerging and developing countries in many ways. Indeed, the technological know-how anchored in imported goods allows companies to use more efficient production processes and increase subsequently the quality of their own products and processes. Contact with suppliers is also beneficial for local businesses (Salomon and Shaver, 2005). Kotabe (1990) examined whether sourcing abroad incites or inhibits innovation capacity of American companies. Using data at the industry level, he confirmed the complementarity between outsourcing and innovation of US multinationals. Bertschek (1995) showed that the share of imports has positive and significant effects on product innovations and processes of German companies because of increased competition in the local market.

4. Methodology

4.1 Sample description

This study includes 15 emerging and developing countries[2]. This choice is based on the limited data concerning the variable human resources in research and development.

The study uses data for the period of 2000-2010.

4.2 Data

4.2.1 Dependent variable

The dependent variable in our model (PAT) is defined as the number of patent applications filed by residents of a country in the USPTO for a given year.

As the level of international patenting is observed with a time lag, our empirical work requires a lag of 2 years between explanatory variables and the dependent variable. Therefore, data for independent variables are for the period 2000-2010, and patent applications relate to the period 2002-2012.

4.2.2 Independent variables

a. Human resources

To test the research hypotheses, we use two human resource measures. The first reflects the specific human capital in R&D activity. This is the share of R&D staff in the labour force (**HRD**). The data represent the proportion of R&D personnel in the labour force of 1000 people (Data source: UNESCO).

The second measure reflects general human capital. This is the variable (**TER**) representing the enrolment rate in tertiary education.

b. The knowledge stock

The knowledge stock can be measured in two ways: direct (stock of patents) and indirect (real GDP per capita) (Furman et al., 2002; Hu and Mathews, 2005; Porter and Stern, 2000). The patent stock is the sum of patents until time t - 1 (Porter and Stern, 2000). Real GDP per capita captures the

[2]Argentina-Bulgaria-Croatia-Hungary-Latvia-Madagascar-Malaysia-Mexico-Panama-Praguay-Poland-Romania-Russia-Thailand-Turkey.

ability of a country to translate its knowledge stock into a realized state of economic development (Furman et al., 2002).

This paper uses both of these measures noted (**PATS**) and (**GDP**). Data are respectively from USPTO and Penn World Table 7.1.

c. The institutional framework

Institutions' quality is measured by the index of economic freedom of Economic Freedom of the Word Report (Gwartney et al., 2014) taking a value between 1 and 10 (**EF**). The same measure is used by Chen and Puttitanun (2005) and Kanwar (2007).

d. The size of the country

The country's size is measured by the number of the population in thousands (**POP**). This measure is used by Furman et al. (2002) and Chen and Puttitanun (2005). Data are from World Development Indicators.

e. Imports of high technologies

Imports of high technologies are measured by the level of imports of high-tech goods. Data are collected from United Nations Commodity Trade Statistics Data Base.

So, (**IMP**) represents imports of high technologies. This measurement is used by Schneider (2005). The product groups that are included in this measure are products in classes 7, 86 and 89 of the Standard International Trade Classification (SITC, Rev. 1)[3].

In order to express this variable in real terms, the data are deflated by the Producer Price Index of the United States (PPI base 100 in 2010, according to OECD statistics).

All variables are in natural log. Summary statistics for the variables are given in Table 1.

4.3 Presentation of models

The regression model for the innovation function is constructed by taking the natural log of Equation 3 in section 1, and including the control variables and the time fixed effects in the model:

$$\text{Log}(\acute{A}) = \theta \log(A) + \psi \log(H_A/L) + \beta \log(Z) + \mu + \varepsilon \quad (4)$$

$\acute{A}$, A et H_A/L are respectively technological innovation, knowledge stock and the ratio of the full time equivalent researchers devoted to R&D to total labour force.

Z is a matrix of control variables; μ is time fixed effects and ε is regression residuals.

$$Z = (TER, POP, EF, IMP).$$

In order to test Hypothesis 2, we introduce an interaction term of full time equivalent researchers and technologies imports (**HRDI**).

The general form of the linear model is the following:

$$PAT_{it+2} = \beta0 + \beta1\ HRD_{it} + \beta2\ TER_{it} + \beta3\ PATS_{it-1} + \beta4\ GDP_{it} + \beta5\ POP_{it} + \beta6\ EF_{it} + \beta7\ IMP_{it} + \beta8\ HRDI_{it} + \varepsilon_{it} \quad (5)$$

In this paper, three models are tested :

$$PAT_{it+2} = \beta0 + \beta1\ HRD_{it} + \beta2\ TER_{it} + \beta3\ PATS_{it-1} + \beta4\ POP_{it} + \beta5\ EF_{it} + \varepsilon_{it} \quad (6)$$

$$PAT_{it+2} = \beta0 + \beta1\ HRD_{it} + \beta2\ GDP_{it} + \beta3\ POP_{it} + \beta4\ EF_{it} + \beta5\ IMP_{it} + \varepsilon_{it} \quad (7)$$

$$PAT_{it+2} = \beta0 + \beta1\ HRD_{it} + \beta2\ GDP_{t} + \beta3\ IMP_{it} + \beta4\ HRDI_{it} + \beta5\ POP_{it} + \beta6\ EF_{it} + \varepsilon_{it} \quad (8)$$

PAT = number of patent applications filed in the USPTO ; HRD= share of human resources devoted to R&D in total labour force ; TER = enrolment rate in tertiary education ; PATS = patents stock; GDP= reel GDP per capita ; POP = number of population ; EF = economic freedom index; IMP = importations of high technologies, HRDI = HRD*IMP.

All variables are in natural logarithm.

[3] Class 7 includes machinery and transport equipment. The class 86 includes instruments (optical, medical and photographic), watches and clocks. The class 89 includes various manufactured goods. This definition is similar to that used in Schneider (2005).

5. Empirical results and analysis

The Lagrange multiplier test shows that it is necessary to introduce individual effects in the models. The Hausman test allows us to choose fixed effects model for Models 1 and 2, and random effects model for the Model 3[4].

According to correlation matrix, higher correlations are found between patent sock and importations (0,84 > 0,80) and between GDP per capita and tertiary education (0,87 > 0,80). Thus, these two sets of variables should not be introduced in the same model in order to guarantee reliability of results.

Test of heteroscedasticity confirms the presence of heteroscedasticity problem only for the Model 1. Test of error for auto correlation confirms the absence of auto-correlation problem in the three models.

The following table (Table 2) provides the results[5] of analysis of the three models.

According to regression results, Fisher statistics in Models 1 and 2 and Chi-square statistic in Model 3 testing the joint significance of explanatory variables are significant at 1% in the three models. They permit rejection of the null hypothesis that the regression coefficients β are zero.

Consistent with our first hypothesis, the results of multiple regression Model 1 show that human resources devoted to R&D have a significant positive effect on the level of technological innovation. Interpreting the coefficients as elasticities, Model 1 implies that, all things being equal, a 10% increase in the share of researchers in total labour force is associated with an increase of 2.39% in the level of international patenting. This result corroborates the findings of Furman et al. (2002), Jaumotte and Pain (2005b) and Ulku (2007). It allows us to show the

Table 3. Regression results of models 1, 2 and 3

Independent variables	Predited sign	Model 1		Model 2		Model 3	
		Coefficients β	**t**	**Coefficients β**	**t**	**Coefficients β**	**z**
Constant		5,21	0,57	-21,692	-2,41**	-24,352	-7,48***
HRD	+	0,239	2,21**	0,335	2,79***	0,365	1,02
TER	+	0,905	2,02*				
PATS	+	0,214	2,09*				
GDP	+			1,589	4,06***	1,291	4,47***
POP	+	-1,228	-1,40	0,534	0,68	0,985	5,84***
EF	+	3,123	2,07*	3,573	5,36***	3,716	5,86***
IMP	+/-			-0,117	-0,89	-0,052	-0,48
HRDI	+					-0,002	-0,06
N		162		161		161	
R2 (Within/ Between)		0,55		0,56		0,89	
F / Chi2		31,83***		36,83***		303,50***	
*, **, *** : coefficients are significant at 10 %, 5 % and 1 %. All variables are in natural log. Models 1,2 and 3 are respectively related to equations (6), (7) and (8) defined in section 3.							

[4] Models 1, 2 and 3 are respectively related to (6), (7) et (8) defined in section 3.

[5] We use the software STATA 10 for estimation of the models.

importance of specific R&D human capital in the innovation process. It claims the assumption of endogenous growth models without scale effect that an increase in the share of researchers in total labour force leads to an increase of innovation.

The general human resources also increase the level of innovation. In fact, the coefficient on this measure is positive and significant at 10% level. It implies that a 10% increase in enrolment in higher education leads to a 9% increase in the level of international patenting. Note that general human capital has a more intense effect on technological innovation than the specific human capital of innovation activity. This result supports the assertion of the World Bank (2010) about the extreme usefulness of general skills with respect to the specialization in the context of developing countries. In fact, research and development is only part of the innovation process, which requires further skills for the acquisition, use and exploitation of technologies.

Our findings highlight the importance of technological innovation in the two types of human capital, ie the specific human capital in R&D activity and especially the general human capital. Thus, we validate hypothesis 1.

For the other variables of the Model 1, we find that the stock of patents has a positive and significant sign at 10% level. An increase of 10% of patent stock leads to an increase of 2.14% in the number of patents. This result is consistent with the results found by Porter and Stern (2000), Furman et al. (2002), Schneider (2005) and Teixeira and Fortuna (2010). It validates the hypothesis of endogenous growth theories asserting a positive effect of knowledge stock on innovation. It also confirms that the two factors highlighted by growth theories (human capital of R&D and knowledge stock) have almost equal weights (2.39% vs 2.14%) in explaining the level of technological innovation in emerging and developing countries.

The coefficient of the index of economic freedom is positive (3.123) and significant at 10% level. This result shows that the institutional framework is favourable to innovation in the countries of our sample. It corroborates the findings of that of Mahagaonkar (2008) and Tebaldi and Elmslie (2013).

The population has no significant effect.

Given the context of our study, the Model 1 is not sufficient to explain technological innovation in EDC, which is partly an activity of adoption, use and adaptation of foreign technologies. That is why we introduce in the Model 2 a proxy of foreign sources of knowledge, namely the import of technology.

The results of Model 2 show that imports of high technology don't have a significant effect on the level of innovation. By contrast, the stock of knowledge measured by real GDP per capita and R&D staff have a positive and significant effect at 1% level. This result proves that imports and R&D are substitutes in the production of innovations.

Results show that importation of technologies is not a significant source of new technologies. Countries studied pay rather particular attention to internal R&D activities. Such internal R&D efforts play a significant role in innovation suggesting the need for a policy encouraging investment in R&D.

To find out if there is an indirect effect of R&D human resources on technological innovation, we introduced a third Model with an interaction term of full time equivalent researchers and technologies imports (**HRDI**). Results of Model 3 show that in accordance with the results of model 2, imports do not have a significant effect on technological innovation. The interaction term is not significant in explaining the production of international patents. This result is not consistent with the hypothesis of the absorption capacity. It shows the mismatch between the skills of emerging and developing countries and imported technologies. Thus, the indirect effect of R&D resources through its interaction with foreign sources of knowledge does not exist in the countries studied. Therefore, hypothesis 2 is not substantiated.

The results of the third model also show that the stock of knowledge measured by real GDP per capita affects positively and significantly (at 1% level) the number of patents applications filed in the USPTO.

For the control variables, the effects are the same as that of in the previous models. However, the population has a positive and significant impact on innovation. This result highlights the benefits of economies of scale and agglomeration effects of the population. It corroborates the results of Chen and Puttitanun (2005), Lerner (2002) and Furman et al. (2002).

In summary, results allow us to identify the following two points:

- Human capital (general and specific) as well as the stock of knowledge can improve the level of technological innovation.
- Investment in foreign technology does not improve innovation even if it is accompanied by a local effort in R&D.

From these results, we can say that countries of our sample exceeded the learning phase by using foreign technologies, to move to a phase of learning through research, where local R&D efforts (physical and human investments) have a greater impact on technological innovation.

Conclusion

The objective of this paper was to evaluate the role of human capital in technological innovation in emerging and developing countries. To do this, we presented in the first section a theoretical background. The second section summarizes empirical studies relative to the effect of human resources on innovation. It appears from this section that human capital affects innovation in both direct and indirect ways. To test these hypotheses, we use the model of Dinopoulos and Thompson (2000). The application of this model to a sample of 15 countries over the period 2000-2010 shows that specific and general human resources affect positively and directly innovation. By contrast, we do not confirm their indirect effect. We conclude that the promotion of human resources is an effective direct tool of public innovation policy.

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