

Knowledge Production and Economic Development: Empirical Evidences

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Abstract This paper throws some light on the relationship between domestic knowledge production and economic development for a group of countries in different periods of time. In particular, this article presents a statistical analysis using the Qualitative Comparative Analysis (QCA) method and corroborates that there is a strong relationship between economic development and the domestic capacity to produce new knowledge. We use as a proxy for domestic knowledge production the patent application by residents and the metric of income level used was the GDP per capita. We show that an increase in the stock of knowledge produced by residents is an important policy to generate income in an economic system once residents are able to appropriate the gains for the use of this new knowledge. Accordingly, there is a dual effect: Knowledge stock growth has a positive impact on GDP, and GDP growth leads to increases in resources to be used for new knowledge generation. In times of global value chains and capital mobility, incentivizing creative imitation, absorption, and production of new knowledge seems to be a valid strategy for less industrialized countries.

Keywords Economic development · IPR · Innovation system

JEL Classification O14 · O25 · O34

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Introduction

Intellectual Property Rights (IPRs) allow companies to maintain their market power on one hand, but on the other, they create incredible barriers to learn from copying and from reverse engineering for catching-up companies in less industrialized nations, hindering their development, which on its turn is associated with creative imitation and absorption (Archibugi and Filippetti 2010).

IPRs were intensified worldwide from the 80s and 90s, when we witnessed a process of trade liberalization and an intensification of companies' integration into the global economy. This period coincided with the phenomenon of outsourcing and the emergence of global value chains which represents a reorientation of multinational companies' strategies (Gereffi 1999), and has different impacts on different national economies.

Along with the distribution of productive activities by multinational companies (what is called production fragmentation), there is also the distribution of R&D activities on a global scale; however, they are still pretty much concentrated in developed nations—that is, the USA, Japan, and (east) Europe (Chesnais 1996; Chesnais 2010). The distribution of tangible and intangible inputs necessary to global production activities and their results obeys specific strategies defined by multinational companies which control global value chains. This means that the overall picture of learning and competence building, “knowledge fencing” and catching-up becomes more critical, and it depends on countless strategies structured by the leaders in different global value chains.

There is a large body of literature that already presented the limits of IPRs, the impacts of foreign direct investment (FDI), and trade liberalization for companies in a catching-up process in less industrialized nations such as in Vaitos (1972), Penrose (1973); Lall (1980); Correa (1997); Maskus (2000); Sell and May (2001); Coriat (2002); Michalopoulos (2003); Chang (Chang 2003, 2004, 2009); Sell (2004); Lai (2007); Branstetter et al. (2007), and Kascheva (2013) just to name a few. Our objective here is to give emphasis to the fact that IPRs, on one hand may encourage inventive activities and industrial innovation; however, on the other, promote an extra impediment to companies' learning, especially for those with reduced resources to access protected knowledge and those that integrate global value chains in activities with low value added. Therefore, IPRs generate additional costs for catching-up companies. We do not intend to make a comprehensive compendium of all literature available regarding the pros and cons of IPRs, which is too large to be reviewed here and it had been done elsewhere.

In short, we aim to answer the following questions: Is domestic knowledge production an important feature of relatively more developed nations? Our hypothesis is that new knowledge creates cumulative advantages for those who create it and for those who have access to and have capacity to absorb and use it. In consequence, domestic knowledge production is a crucial asset for economic development.

Results presented in this paper show that national efforts to increase the production of new relevant knowledge whose proxy is the percentage of patent applications by residents¹ who are closed linked with nations with high GDP per capita levels, suggesting that there may be a bi-directional correlation between these two variables.

¹ Residents' Patent applications can then be used as a proxy of the level of technological competence of a country but also the level of domestic knowledge that is appropriated by residents.

Prior to launching into the discussion, we shall present the structure of our paper: Firstly, we introduce our interpretative framework, i.e., for the individual company, IPRs increase the appropriability conditions but in a macro perspective, it reduces the nation's learning opportunities. After, we propose the methodology we use to test our hypothesis. To test it through a Qualitative Comparative Analysis (QCA), we use secondary data from the World Intellectual Property Organization (WIPO) and from the World Bank, then we show the model estimation results. Finally, we present some discussions and concluding remarks.

IPR and Evolutionary Economics

Micro Perspective

Technological appropriability conditions show the possibilities of protecting new knowledge and also the profits which can be gained from innovative activities. Companies use therefore a variety of means in order to protect their new knowledge, for example, keeping it as a secret, through IPRs or constantly innovating (learning advantage).

It has being argued that an economic system able to protect the production of new relevant technological knowledge enables more innovations since it expands companies' appropriability conditions. A company would be incentivized to create new knowledge once it would be able to appropriate the gains of this uncertain investment.

In a micro perspective, we understand that companies are organizations with specific competences at doing something (Malerba and Orsenigo 1993). Such competences have a tacit nature and are organized in routines which guide decision-making. Companies can be also understood as organizations capable of learning (Nelson and Winter 2005 [1982])—no matter if they are located in a more or less developed country or if they are big or small companies; they learn more or less promptly and more or less effectively.

Not only is learning the development of competences (Nelson 1992), but it is also the absorption of already existing knowledge produced elsewhere and the generation of its improvements (Viotti 2002). Learning is to a large extent, local, and path-dependent. By the same token, when a company is exposed to new knowledge and if it has enough competences to absorb and use it, we say this company has learnt. In order to absorb new knowledge, companies need to make huge efforts (Cohen and Levinthal 1990; Archibugi and Filippetti 2010) to build new competences and upgrade the ones they already have (Borrás and Edquist 2015).

A company learns from external sources, but it also learns from different internal sources. The types of learning, either external or internal, depend on the organization's absorptive capacity but also on the "degree" of knowledge tacitness involved. For instance, there is tacit knowledge acquired through learning by doing, using, and interacting (DUI-mode), and also explicit knowledge acquired through science, technology, and innovation (STI-mode) (Jensen et al. 2007). Companies' learning ability is defined by the technological environment, i.e., the nature of the problems that company has to solve influences its innovative activities, the incentives, and constraints to particular strategies it is going to pursue (Malerba and Orsenigo 1993).

Available knowledge—either tacit or explicit—is therefore the main ingredient in the learning process and the most important output is new knowledge—either entirely

new or improved knowledge. The protection of new knowledge is a preeminent practice if an organization does not want to allow it to be freely available for its competitors. Tacit knowledge is by definition more difficultly transferred and it is held in a secret form while law (property rights) can protect codified knowledge and it is more easily transferred (as it is documented).

The knowledge involved and used in the production and marketing of goods and services, which includes not only scientific knowledge—coming from natural, social, and human sciences, etc., but also empirical knowledge—resulting from observations, experiences, specific competences, and tradition (oral and written)—is what we call technology (Sabato 1979). So, technological knowledge, besides involving scientific knowledge, it involves procedures of a much more tacit nature, often embodied in organizational practices and specific to each technological paradigm (DOSI 1988).

Therefore, when we are speculating about “knowledge fencing,” we are also referring to “technology fencing.” Consequently, if a company protects its knowledge, it is also creating barriers to avoid its technology to flow “freely” to others. This way, patents are used strategically to block rivals’ innovations, to infringe and counter infringe suits against rivals, to signal to financial markets likely streams of future profits, and to deter the entry of newcomers (Marengo et al. 2012).

If one important ingredient for learning is available knowledge, as we mentioned, and if this knowledge is kept in secret or protected by law (with IPRs), other companies—from the same industry or from different ones—are not able to access the main ingredient for learning, thus, technological opportunities are reduced.

The main sources of technological opportunities are advances in scientific understanding and technique, technological advances originating in other industries and other companies, and feedbacks from an industry’s own technology advances (Klevorick et al. 1995). Certainly, company’s competences² are paramount elements to be considered if it wants to open a wider range of opportunities to develop new products and processes, but for now, it is important to call attention to the fact that when technological advances originating in other industries and other companies are somehow protected (by secret of law enforcement), not only is there a reduction of learning but also of technological opportunities.

According to Bessen and Maskin (2009), a patent prevents non-holders from the use of that knowledge protected by the patent itself and it slows down innovation rates. This is so because technology is sequential and it evolves by a process of self-creation: New technologies are constructed from ones that already exist, and these offer themselves as possible building-block elements for the construction of still further technologies³ (Arthur 2011). In other words, new technologies are built from a set of existing

² According to Borrás and Edquist (2015, p. 4), individual competences—“acquisition of information, knowledge, understanding, and skills by individual people, through participation in some form of education and training, whether formal (for example in educational institutes) or informal (for example competence building (‘learning-by-doing’) in the workplace)”—are also important for innovation.

³ “How technology evolves” is the central question in technology (...). Without evolution—without a sense of common relatedness—technologies seem to be born independently and improve independently. Each must come from some unexplained mental process, some form of “creativity” or “thinking outside the box” that brings it into existence and separately develops it. With evolution (...), new technologies would be birthed in some precise way from previous ones, albeit with considerable mental midwifery, and develop through some understood process of adaptation. In other words, if we could understand evolution, we could understand that most mysterious of processes: innovation” (Arthur 2011, p. 15).

technologies, from a combination of existing technologies. In consequence, patents prevent infinite combinations. Bessen and Maskin (2009) support this argument by showing that in the last 40 years, the most innovative industries, i.e., computers and semi-conductors, had weak patent protection and rapid imitation of their products. However, with the rapid strengthening of IPR protection in the 80s, there was an inhibition of innovation promotion. For Marengo et al. (2012), it might well happen that companies would be better off in environment characterized by easy imitation.

Macro Perspective

From these previous notions, it is deductible that a country's innovative performance is largely dependent on individual companies' learning capacity, their competence stocks, and their ability to build new competences and upgrade them constantly. Those countries that were able to successfully develop were those that fostered the increase in knowledge stock and fostered both companies and individuals learning through imitation.

It means that the individual–company perspective regarding technological appropriability is not exactly the same for the innovation system learning economy. When considering the entire economy, the lower the degree of appropriability, the bigger the intensity of imitation activities. It happens because the relevant knowledge base increases and the access to it is facilitated. “Without imitating it is impossible to learn and innovate.” (Archibugi and Filippetti 2010, p. 138).

National efforts to increase the production of knowledge can be provided by different indicators: input (e.g., public expenditure on R&D), output (e.g., scientific and technical journal articles, resident intellectual property applications), and outcome (e.g., high-technology exports, receipts for the use of intellectual property)⁴. If we plot, for example, the production of knowledge—let us assume as its proxy, as the percentage of resident patent⁵ grants by GDP per capita, we can clearly see a correlation between the two, suggesting that the more knowledge produced by residents, the bigger the GDP per capita.

Some countries, like South Korea, were able to catch-up in terms of technological development with more developed countries and they have constantly increased their GDP per capita since the 80s, while others—in particular those from Latin America—were not able to. Brazil, Argentina, Mexico, and South Korea had pretty much the same GDP per capita until the beginning of the 1980s from when they start to differ⁶; the same can be said about the knowledge produced by residents (Fig. 1).

⁴ For an assessment on Science and Technology metrics, see Geisler (2000). For a critique on the use of patents as an economic indicator, see Desrochers (1998).

⁵ It is worth mentioning that a patent entitles an eligible right used to defend (by legal protection) competitive advantages of successful innovative companies, it does not constitute, necessary or sufficient condition to ensure the success of innovation or favorable appropriability. The establishment of a legal monopoly does not automatically translate into an effective economic monopoly position (Possas and Mello 2009). Therefore, a patent *per se* does not guarantee *ex ante* that there will be an economic monopoly position for the owner of the patent. It will depend obviously of its relevance to the productive sector and if it can be applied in production affecting the costs and/or differentiating products. What is important to mention is that having a patent does not mean the company has innovated or will ever innovate. According to Dressler (2012), due to the lack of a sufficient economic theory of patents, an assessment of the economic effects of patents cannot be conclusive, thus, any economic justification of a patent system is biased.

⁶ For a further analysis about the Brazilian case compared to the South Korean, please see Romero et al. (2015).

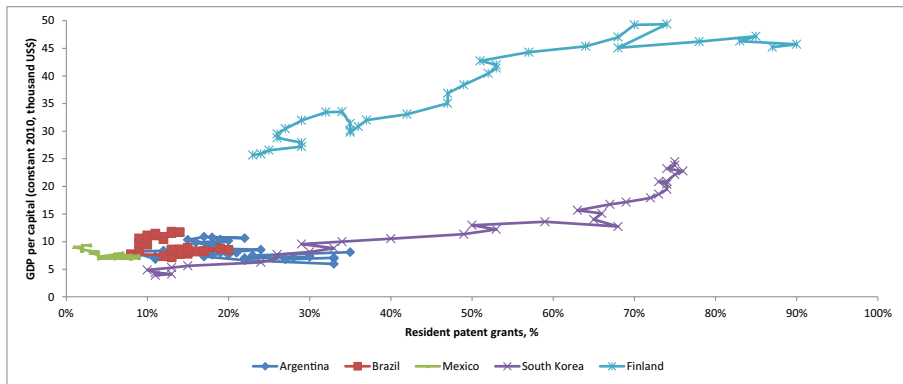


Fig. 1 GDP per capita and percentage of patents granted to resident, selected countries, 1980–2014. Source: Authors' own. Data sourced from the World Bank and from WIPO

According to Schumpeter (1985 [1911]), economic development is the generation, application, and dissemination of new knowledge within the economic system. In this sense, the residents' ability to generate new knowledge can be used as a proxy of the nation's technological competence materialized in patents. Therefore, an increase in the total generation of knowledge by residents is an important factor to generate income in an economic system once residents are able to appropriate the gains for the use of this new knowledge. We acknowledge that this causality is not as direct as presented, there is a dual causal effect here: Knowledge stock growth has a positive impact on GDP, and GDP growth leads to increases in resources to be used for new knowledge generation.

Methodology and Database

The idea behind this paper is to test the hypothesis of the relevance of knowledge production by residents to economic development. As a proxy for knowledge creation, we could have used some indicators as articles published in domestic and international journals, patent applications (deposits), patent publications, or patent granted (issued or registered).⁷ In this paper, we make use of patent application data available once the patenting granting process in many offices is sluggish. In some cases, applicants have to wait 11 years for the filed patent to be examined and to be finally approved (if it is the case), as what happens in Brazil.⁸ The

⁷ Patent application (or deposit) is a request pending at national intellectual property office for the grant of a patent for the invention described and claimed by that deposit. Prior to publication (generally patents are published at about 18 months after the earliest priority date of the application), the application is confidential to the national intellectual property office. After publication, depending on each office rules, certain parts of the application file may remain confidential. The publication of a patent application marks the date at which it becomes publicly available. Once the patent application complies with the requirements of each national intellectual property office, the patent will be granted/issued/registered.

⁸ Information available at <www.managingip.com/Article/3501851/Brazils-battle-against-the-patent-backlog.html>

backlog of unexamined patents at the Brazilian National Institute of Industrial Property (*Instituto Nacional de Propriedade Industrial*—INPI) is massive. Using patent application by residents as a proxy for domestic knowledge, production can be a limitation of the data we are going to present in this paper as an application/deposit consists of a description of the invention, and it does not guarantee at all that the property right will be granted. This choice is justified once the focus of this article is the analysis of technology trends of patenting, and the time delay caused by the examining process would preclude this kind of analysis.

Once we have selected our proxy for knowledge production, we can evaluate the relationship between patent deposits by residents and economic development. The metric for economic development is the standard proxy of income per capita, i.e., GDP per capita. GDP per capita is frequently used as a development economic measure at country level since measures as Human Development Index (HDI) or others closed linked to economic development are hard to be calculated and collected, mainly at a long run historical perspective.

It is also necessary to call attention to the fact that to evaluate this relationship, we ought to statistically control our model using other important variables already presented in the literature. We choose to use Qualitative Comparative Analysis (QCA), a very popular technique in social sciences. By using QCA, it is possible to assess causation effects which are very complex, where different combinations of causal conditions are capable of generating the same outcome (Rihoux and Ragin 2009). This choice is made because a series of factors, among them “conjunctural causation” across observed cases, which means that one factor or a set of different factors may lead to the same result. Besides that, other particularities of QCA are useful for our purposes, but they shall be discussed later.

Regarding conjunctural causation, for example, take A , B , C , D , E as possible conditions to generate the outcome Y . So, QCA may conclude that the set of factors AB or ACD are able to generate Y (AB or $ACD \rightarrow Y$). Or, depending on the context, the absence of a factor can be important to generate the outcome: $AB \rightarrow Y$, but also $aC \rightarrow Y$, where (a) is the absence of factor (A). In other words, let us say that high level of patent application by residents (henceforth named P) and a mature innovation system (named I) generate high domestic income (Y), so QCA model generate $PI \rightarrow Y$.

Here, we are using QCA by fuzzy sets (fsQCA), which permit membership scores in the interval between 0 and 1 (in a continuous way). So, all data are standardized at this interval. The basic idea is to allow scaling membership scores and the possibility of providing partial membership. fsQCA addresses the varying degree to which different cases belong to set, since full membership to full nonmembership. In a nutshell, inside our database, a country might receive a membership score of 1 in GDP/capita (which means that it has the highest GDP/capita in the database) but a score of 0.8 in the set of innovation system. So, this country is full membership at GDP/capita series and strong but not full membership at innovation system series.

In a continuous fuzzy set, we can describe the following membership degrees:

- a. 1 fully “in”

- b. $0.5 < x_i < 1$: degree of membership is more “in” than “out”
- c. $0.5 > x_i > 0$: degree of membership is more “out” than “in”
- d. 0 fully “out”

The used approach to evaluating the relationship between the outcome and explanatory variables when using fuzzy sets is the inclusion ratio (Longest and Vaisey 2008):

$$I_{XY} = \sum \min(x_i, y_i) / \sum x_i.$$

in which X denotes the predictor configuration (e.g., AB), Y denotes the outcome set, x_i is each case’s membership in the configuration X , and y_i stands for each case’s membership in the set Y . Considering conditional probabilities, the closer the value of I_{XY} to unity, the greater the consistency of the data with the assertion that X is a subset of Y ($X \rightarrow Y$). Different methods can be established to decide whether each configuration of predictors (X) should “count” as a (probabilistically) sufficient condition for Y . Following Ragin (2000, 2006), in this paper is determined a numeric benchmark (0.700) where will be coded all configurations for which $I_{XY} > 0.700$ is sufficient. Thus, a minimization procedure is implemented and then it identifies the simplest set of conditions that can account all the observed outcomes, as well as their absence. The variables suggested are presented in Table 1.

The acronyms (P I E S C T) are used to specify the presence (high level of, with upper-case letters) or absence (low level of, with lower-case letters) of the explanatory variables to explain the outcome variable. For example, the minimum configuration reached by the minimization procedure can be PIEsT (which means that inclusion ratio for this configuration is bigger than 0.700). So, we

Table 1 Variables investigated

Outcome variable

1. GDP per capita (current US\$)

Explanatory variables

2. Share of patent applications by residents (%) (variable P);
 3. Innovation system (variable I): defined as the first factor obtained by the factor analysis technique for the following variables:
 - a. High-technology exports (% of total manufactured exports)
 - b. Researchers in R&D (per million people)
 - c. R&D expenditure (% of GDP)
 - d. Scientific and technical journal articles (% of total amount)
 4. Education (variable E): gross enrolment ratio, tertiary, both sexes (%)
 5. Infrastructure (variable S): electric power consumption (kWh per capita);
 6. Financial system/credit (variable C): sum of domestic credit provided by financial sector (% of GDP) plus foreign direct investment, net inflows (% of GDP)
 7. Open trade (variable T): sum of exports of goods and services (% of GDP) plus imports of goods and services (% of GDP).
-

Source: Authors’ own

can conclude that a configuration with a high level of “*P*” (patent application by residents), “*I*” (innovation system), “*E*” (education), and “*T*” (open trade) and a low level of ‘*s*’ (infrastructure) are able to generate high level of outcome (GDP per capita). The absence of the variable credit in the minimum configuration means that the level of credit is irrelevant.

All the variables are available at the World Bank database, except the share of patent applications by residents which was available at the World Intellectual Property Organization (WIPO) database. We had access to data from 1986 to 2010 however to limit problems related to shocks occurring in specific years, we applied QCA technique for 5-year-average periods (1986–1990; 1991–1995; 1996–2000; 2001–2005; 2006–2010), following the methodology applied by Fagerberg and Srholec (2008). Still, the variables “Researchers in R&D” and “R&D Expenditure” are available just from 1996 on. So, the factor for innovation system in the periods 1986–1990 and 1991–1995 comprises only the two remaining variables (“high-tech exports” and “scientific and technical journal articles”).

It is worth noting that the suggested variables are widely used in papers related to innovation, IPRs, and economic development (Chen and Puttitanun 2005; Schneider 2005; Allred and Park 2007; Hudson and Minea 2013).

A first selection was done considering the quality of information regarding the share of patents by residents to select countries. All countries with more than five missing values for this variable during the period 1986–2010 were dropped from the database out. This first choice returned the presence of 50 remaining countries. In a second selection, an intensive work was made to drop out countries with more than two missing values for the other variables in each period. This was used to avoid average bias for indicators, since shocks in 1 year could bias an average calculated only on three or fewer periods. So, after that, a different number of countries were considered for each period of the analysis, depending on the available data for each one. The remaining countries for each period are presented in Table 2.

Before proceeding, we need to explain the use of QCA. According to Ragin (1987), QCA is interesting because we are not required to specify a single causal model that best fits the data, as usually is required in standard statistical techniques. Notwithstanding that, QCA allows considering specific, distinct patterns and “outliers”, which also is not possible in descriptive statistical analysis or econometric regressions (computed across all cases at the same time) (Rihoux and Ragin 2009). Therefore, this statistical method is important in considering and presenting different development pathways for countries around the world. In this paper, for instance, we are able to differentiate developed countries whose share of patent applications by residents is important from those whose share of patent applications by residents is not, considering other relevant variables as presented in Table 1. This feature is interesting when comparing the best fit configuration of explanatory variables for each country, what will be done in Table 5.

We also opt to use this statistical method because it does not require the establishment of a traditional economic growth equation in a theoretical level, since the aim is just to capture empirical causal relations of relevant factors on economic development—and not a causality relationship among a dependent variable and independent

ones. Relaxing this assumption is interesting since it is not required a strict definition about the causality direction among the share of patent applications by residents and GDP per capita, for example.⁹

And last but not the least, assumptions of statistical techniques are not required, for example those about multicollinearity and heteroscedasticity. It would be a problem as we are using share of patent applications by residents, different proxies for innovation system and education; the strong correlation between these variables could generate bias on the coefficients in a regression analysis.

Model Estimation Results

In Table 3, we presented a preliminary analysis regarding descriptive statistics of the variables. An increase of more than 126% can be seen to GDP per capita average comparing the first period (1986–1990) and the last (2006–2010) (Table 2). Despite that growth, inequality is present in all periods when we compare minimum and maximum values, and this same behavior is seen in all other series. It is an indicative to understand the sample as a good measure of reality. Still, sample variability is important for QCA technique once it allows a better comparison among configurations.

It can be seen an increase on average in all explanatory variables, especially for education (gross tertiary education enrolment ratio), share of patent applications by residents, and innovation system. By the way, education has variation of average compatible with GDP per capita, which would indicate its relevance for economic development. It is worth to note too that the share of patent applications by residents has a considerable increase, just less than education level. So, considering that, it may be a first evidence about the importance of this variable.

Now we present results from QCA technique. As stated before, QCA implements a minimization procedure that identifies the simplest set of conditions that can account all the observed outcomes, as well as their absence. Following this, it is presented below these minimization procedures ensuring the configurations that have y consistencies significantly greater than 0.700, as well as significantly greater than their n consistencies. It means that results consider those minimum configurations of the 30% top GDP per capita countries.

A simple explanation has to be made before proceeding to the analysis. All explanatory variables were defined as a single letter, as presented in the methodology section of this paper. So the results in Table 3 and so on highlight these letters either in a lower or upper case letter. For example, if a minimum configuration is PiES it means that high share of patent application by residents, immature innovation system,¹⁰ high education level (gross tertiary education enrolment ratio), and high infrastructure level (electric power consumption per capita) leads to high levels of GDP per capita.

⁹ Despite the usual understanding about patent (proxy for knowledge production) defining economic development, some studies show that the increase on trade liberalization and FDI tends to establish a realignment between good production in developing countries and knowledge production in developed ones (LAI 2007; Branstetter et al. 2007). On these results rest out the additional hypothesis of a new causality direction from economic development to the capability of generating domestic knowledge. The findings in this paper are not conclusive to answer these questions.

¹⁰ Innovations systems are classified as Albuquerque (1999) in a mature and immature typology.

Table 2 Selected countries according to each selected period

| Period number | 1986–1990 | 1991–1995 | 1996–2000 | 2001–2005 | 2006–2010 |
|---------------|----------------|-----------------|----------------|----------------|-------------------|
| Countries | Austria | Algeria | Argentina | Algeria | Argentina |
| | Bangladesh | Argentina | Austria | Argentina | Austria |
| | Brazil | Austria | Belgium | Austria | Belgium |
| | Canada | Brazil | Brazil | Belgium | Brazil |
| | Chile | Canada | Bulgaria | Brazil | Bulgaria |
| | Denmark | Chile | Canada | Bulgaria | Chile |
| | Finland | China | China | China | China |
| | France | Colombia | Colombia | Colombia | Colombia |
| | Greece | Denmark | Denmark | Denmark | Denmark |
| | Iceland | Egypt, Arab Rep | Finland | Finland | Egypt, Arab Rep |
| | India | Finland | France | France | Finland |
| | Indonesia | France | Germany | Greece | France |
| | Ireland | Germany | Greece | Guatemala | Greece |
| | Israel | Greece | Hungary | Hungary | Guatemala |
| | Japan | Guatemala | Iceland | Iceland | Hungary |
| | Korea, Rep. | Hungary | India | India | Iceland |
| | Malaysia | Iceland | Indonesia | Indonesia | India |
| | Mexico | India | Ireland | Ireland | Indonesia |
| | Netherlands | Indonesia | Japan | Japan | Iran, Islamic Rep |
| | New Zealand | Ireland | Korea, Rep. | Korea, Rep. | Ireland |
| | Norway | Israel | Malaysia | Malaysia | Japan |
| | Portugal | Japan | Mexico | Mexico | Korea, Rep. |
| | Romania | Korea, Rep. | Netherlands | Netherlands | Malaysia |
| | Spain | Malaysia | New Zealand | New Zealand | Mexico |
| | Sri Lanka | Mexico | Norway | Norway | Netherlands |
| | Sweden | Netherlands | Poland | Philippines | New Zealand |
| | Switzerland | New Zealand | Portugal | Poland | Norway |
| | Thailand | Norway | Romania | Portugal | Philippines |
| | Tunisia | Peru | Spain | Romania | Poland |
| | Turkey | Philippines | Sweden | Spain | Portugal |
| | United Kingdom | Poland | Switzerland | Sweden | Romania |
| | United States | Portugal | Thailand | Switzerland | Spain |
| | | Romania | Tunisia | Thailand | Sri Lanka |
| | | South Africa | Turkey | Tunisia | Sweden |
| | | Spain | United Kingdom | Turkey | Switzerland |
| | | Sri Lanka | United States | United Kingdom | Thailand |
| | | Sweden | Uruguay | United States | Turkey |
| | | Switzerland | | Uruguay | United Kingdom |
| | | Thailand | | | United States |
| | | Tunisia | | | Uruguay |
| | | Turkey | | | |

Table 2 (continued)

| Period | 1986–1990 | 1991–1995 | 1996–2000 | 2001–2005 | 2006–2010 |
|--------|-----------|----------------|-----------|-----------|-----------|
| number | 32 | 44 | 37 | 38 | 40 |
| | | United Kingdom | | | |
| | | United States | | | |
| | | Uruguay | | | |

Source: Authors' own

All QCA procedures for periods present consistent statistical results with high total coverage and solution consistency, which is an indication for the relevance of the minimum configurations. To understand results, consider the period 2006–2010. In that, the minimum configurations of the countries in the top 30% of GDP per capita (i.e., 12 of the 40 countries presented in Table 2) are PISCT, PIEST and IESC. In other words, high level of GDP per capita is explained in some countries by PISCT (i.e., a combination of high share of patent application by residents, mature innovation system, high infrastructure level, high level of credit, and open economy), in other countries by PIEST (i.e., a combination of high share of patent application by residents, mature innovation system, high education level, high infrastructure level, and open economy), and finally by IESC (i.e., a combination of mature innovation system, high education level, high infrastructure level, and high level of credit).

For all periods, there is strong evidence of the importance of the share of patent applications by residents, excluding one single minimum configuration of 1986–1990 period (pES). Even so, the majority of the other configurations in the same period presents high patent share by residents as crucial for economic development. For the entire period, 15 of 21 minimum configurations highlight high share of patent applications by residents as an important variable for countries with highest GDP per capita. It is worth to be noted that almost all suggested variables also present relevance to explain economic development, just being “international trade” (5 of 21 minimum configurations) of low importance. Those are the case for innovation systems (17 of 21 minimum configurations), education (16 of 21), credit (14 of 21), and infrastructure (14 of 21). In a nutshell, the share of patent applications by residents presents as important as these another variables.

When looking for results inside the periods, another important information emerges. Since 1991–1995 period, just one minimum configuration in each period does not have the share of patent applications by residents as an important element for economic development. In all other configurations, distinct combinations of other variables are combined with the share of patent applications by residents to provide the expected outcome. Besides that, there is no necessary and/or sufficient condition for any period, but the share of patent applications by residents, innovation system, and education are present in all but one of the minimum configuration since 1991–1995 period. The importance of a mature innovation system and high level of education for development is well-remarked in the literature (Edquist 2000; Lundvall et al. 2002). Thus, if the result points out that share of patent applications by residents is as important as innovation system and education, it is an important notation to the knowledge appropriability' relevance within countries. Moreover, it is expected that the higher

Table 3 Descriptive statistics

| Period | Descriptive statistics | GDP per capita (US\$) | Share of patent application by residents (%) | Innovation system ^(*) | Education ¹ (%) | Infrastructure ² (Kwh per capita) | Credit ³ (% of GDP) | Trade ⁴ (% of GDP) |
|--|------------------------|-----------------------|--|----------------------------------|----------------------------|--|--------------------------------|-------------------------------|
| | Abbreviations | <i>P</i> | <i>I</i> | <i>E</i> | <i>S</i> | <i>C</i> | <i>T</i> | |
| 1986–1990 | Average | 10,916.05 | 0.349 | -0.037 | 24.87 | 5318.88 | 84.43 | 55.84 |
| | Standard deviation | 9340.95 | 0.260 | 0.628 | 16.82 | 5702.42 | 43.87 | 27.01 |
| | Minimum value | 261.37 | 0.027 | -0.576 | 3.76 | 42.90 | 20.99 | 13.55 |
| | Maximum value | 30,699.78 | 0.946 | 2.683 | 81.04 | 22,834.19 | 244.96 | 124.99 |
| 1991–1995 | Average | 11,929.74 | 0.410 | -0.014 | 29.51 | 4743.50 | 79.57 | 55.29 |
| | Standard deviation | 11,698.37 | 0.282 | 0.600 | 18.84 | 5374.48 | 46.59 | 28.11 |
| | Minimum value | 335.01 | 0.019 | -0.506 | 3.42 | 186.71 | 15.33 | 16.52 |
| | Maximum Value | 41,204.69 | 0.927 | 2.859 | 91.90 | 24,067.76 | 269.11 | 167.98 |
| 1996–2000 | Average | 15,934.59 | 0.471 | -0.015 | 41.39 | 6176.52 | 80.94 | 67.98 |
| | Standard deviation | 12,819.00 | 0.325 | 0.955 | 19.06 | 5923.60 | 54.56 | 38.03 |
| | Minimum value | 431.53 | 0.034 | -1.146 | 6.21 | 341.37 | 23.12 | 18.39 |
| | Maximum value | 41,383.65 | 0.897 | 1.861 | 77.43 | 24,759.98 | 293.15 | 202.98 |
| 2001–2005 | Average | 17,749.12 | 0.473 | -0.022 | 47.81 | 5992.48 | 95.74 | 73.89 |
| | Standard deviation | 16,270.47 | 0.333 | 0.988 | 22.42 | 6302.61 | 57.24 | 37.72 |
| | Minimum value | 573.78 | 0.040 | -1.281 | 9.46 | 424.55 | 20.08 | 23.03 |
| | Maximum value | 51,213.61 | 0.925 | 2.049 | 87.99 | 27,743.43 | 307.06 | 202.23 |
| 2006–2010 | Average | 24,752.57 | 0.571 | -0.015 | 54.60 | 6491.88 | 121.10 | 77.29 |
| | Standard deviation | 22,536.49 | 0.352 | 0.971 | 22.96 | 7881.73 | 77.80 | 38.11 |
| | Minimum value | 1080.34 | 0.039 | -1.313 | 15.07 | 421.23 | 0.70 | 24.66 |
| | Maximum value | 84,757.59 | 0.963 | 1.958 | 100.52 | 44,188.80 | 314.30 | 178.44 |
| Δ of average (2006–2010/1986–1990) (%) | | 126.75 | 63.55 | 59.89 | 119.53 | 22.05 | 43.43 | 38.41 |

Source: Authors' own. Data sourced from WIPO for the share of patent applications by residents and from the World Bank for other variables. Proxies used: ¹ gross enrolment ratio, tertiary, both sexes (%); ² electric power consumption (kWh per capita); ³ sum of domestic credit provided by financial sector (% of GDP) plus foreign direct investment, net inflows (% of GDP); and ⁴ sum of exports of goods and services (% of GDP) plus imports of goods and services (% of GDP)

*The negative bias of values for innovation systems indicates that there is a higher incidence of deficient innovation systems in the sample countries. It is worth to remember that these values are relative comparison for first factors of factor analysis

Table 4 QCA analysis by period

| Period | Number of countries | Minimum configuration | Raw coverage | Unique coverage | Total coverage | Solution consistency |
|-----------|---------------------|-----------------------|--------------|-----------------|----------------|----------------------|
| 1986–1990 | 32 | PIECT | 0.420 | 0.003 | 0.803 | 0.968 |
| | | IESC | 0.612 | 0.062 | | |
| | | PSct | 0.339 | 0.004 | | |
| | | PISt | 0.467 | 0.016 | | |
| | | pES | 0.522 | 0.067 | | |
| | | Est | 0.560 | 0.001 | | |
| 1991–1995 | 44 | IESC | 0.611 | 0.068 | 0.762 | 0.973 |
| | | PESC | 0.592 | 0.049 | | |
| | | PISCT | 0.570 | 0.026 | | |
| | | PIEC | 0.547 | 0.003 | | |
| | | PIES | 0.616 | 0.073 | | |
| 1996–2000 | 37 | PIEST | 0.511 | 0.096 | 0.743 | 0.954 |
| | | IESC | 0.598 | 0.090 | | |
| | | PISC | 0.554 | 0.047 | | |
| | | PIEC | 0.511 | 0.003 | | |
| 2001–2005 | 38 | PESCt | 0.438 | 0.013 | 0.804 | 0.958 |
| | | IESC | 0.661 | 0.078 | | |
| | | PISC | 0.630 | 0.047 | | |
| | | PIES | 0.666 | 0.083 | | |
| 2006–2010 | 40 | PISCT | 0.508 | 0.022 | 0.740 | 0.960 |
| | | PIEST | 0.583 | 0.065 | | |
| | | IESC | 0.653 | 0.135 | | |

Source: Authors' own

the level of education and the more mature the innovation system, the more apt is the society to create new knowledge, publishing more scientific articles and asking for more patents.

To establish a second test observing the importance of share of patent applications by residents another exercise is done in Table 5. We compare the best fit configurations of all countries for each period, verifying the occurrence of three combination types, considering the importance of share of patent applications by residents, innovation system, education, infrastructure and credit, as follows¹¹:

- i. PIESC, which means all variables have high values;
- ii. pIESC, which means that the share of patent applications by residents is low and the others are high; and
- iii. all other combinations for these five variables

The above procedure allows isolating the effect of high share of patent applications by residents in countries controlling for other variables that presented relevance for economic development.

¹¹ They were not observed here the distinct combinations for infrastructure, open trade and financial system.

Table 5 Best fit configurations PIESC, pIESC, and others (selected variables)

| | 1986– 1990 | 1991– 1995 | 1996– 2000 | 2001– 2005 | 2006– 2010 | Δ 2006–10/ 1986–90 |
|----------------------------------|---------------|---------------|---------------|---------------|---------------|------------------------------|
| Configuration PIESC | | | | | | |
| Number of countries | 6 | 11 | 12 | 9 | 12 | |
| Average GDP per capita (US\$) | 18,550.19 | 26,259.68 | 27,084.40 | 32,113.54 | 42,453.57 | 128.9% |
| Average share of patents (%) | 62.36 | 74.37 | 78.33 | 78.45 | 83.71 | 34.2% |
| Configuration pIESC | | | | | | |
| Number of countries | 4 | 2 | 3 | 2 | 3 | |
| Average GDP per capita (US\$) | 18,621.03 | 17,158.25 | 24,872.2 | 30,930.7 | 41,391.25 | 122.3% |
| Average share of patents (%) | 16.58 | 18.56 | 21.57 | 26.93 | 40.04 | 141.5% |
| Other configurations | | | | | | |
| Number of countries | 22 | 31 | 22 | 27 | 25 | |
| Average GDP per capita (US\$) | 7559.91 | 6507.60 | 8634.11 | 11,984.12 | 12,532.14 | 65.8% |
| Average share of patents (%) | 30.89 | 32.13 | 34.14 | 39.11 | 47.27 | 53.0% |

Source: Authors' own

The results show there are differences among countries regarding best fit configurations. First of all, countries with best fit configurations PIESC and pIESC have higher GDP per capita and they have grown at higher rates (about the same rate for both groups) in relation to this variable. Considering the average, it points out to an increase on inequality during this time.

Despite the similarity on GDP per capita level and its change rate concerning PIESC and pIESC configurations, there are more countries with PIESC configurations (about a relation 4.4 per 1 in all periods, exception for 1986–1990), which points out for a more persuasive strategy for economic development. Even when considering pIESC configuration, the increase on patent applications by residents among periods is above the average, reaching a growth about 141.5%. Increasing the number of patents deposits by residents has becoming a more important strategy even in these countries. They have not reached yet a share of patent applications that allows to be evaluated as a ‘P’ acronym, with high levels on this variable. But, during the time, they are narrowing the gap if compared to other countries.

It is worth to note that the argument is not in the sense of considering share of patent applications by residents as a sufficient condition for economic development. Instead, the values of GDP per capita and share of patents for the group named ‘other configurations’ show that, despite the increase on share, the inequality in economic development has increased too. It is clear that the conjunction of social, economic, political, environmental factors that in some way are included on the other variables are important to explain economic development. It is not contested in the analysis.

Table 6 Minimum configurations PIEESC and pIEESC (countries)

| | 1986–1990 | 1991–1995 | 1996–2000 | 2001–2005 | 2006–2010 |
|----------------------|---------------|----------------|----------------|----------------|----------------|
| Total | 32 | 44 | 37 | 38 | 40 |
| Configuration PIEESC | | | | | |
| | France | Austria | Austria | Belgium | Belgium |
| | Israel | Switzerland | Belgium | Denmark | Denmark |
| | Japan | Germany | Germany | Spain | Spain |
| | Netherlands | Spain | Denmark | United Kingdom | Finland |
| | Sweden | Finland | Finland | Ireland | Ireland |
| | United States | France | France | Korea, Rep. | Japan |
| | | United Kingdom | United Kingdom | Netherlands | Korea, Rep. |
| | | Japan | Japan | Sweden | Netherlands |
| | | Netherlands | Korea, Rep. | United States | Portugal |
| | | Sweden | Netherlands | | Sweden |
| | | United States | Sweden | | United States |
| | | | United States | | United Kingdom |
| Number | 6 | 11 | 12 | 9 | 12 |
| % of total | 18.75% | 25.00% | 32.43% | 23.68% | 30.00% |
| Configuration pIEESC | | | | | |
| | Canada | Canada | Canada | Iceland | Iceland |
| | Denmark | Israel | Norway | New Zealand | New Zealand |
| | Ireland | | New Zealand | | |
| | Norway | | | | |
| Number | 4 | 2 | 3 | 2 | 2 |
| % of total | 12.50% | 4.55% | 8.11% | 5.26% | 5.00% |

Source: Authors' own

However, our argument is guided by the ‘Red Queen Effect’ (Ribeiro et al. 2006), which consider that a developing country would have to run twice as fast – in terms of its innovation system – to improve its catching up. For us, the internal knowledge production follows this idea, since developing countries (other configurations) seem to have walked at a slower speed than necessary to provide internal capabilities of knowledge, and countries belonging to pIEESC configuration have sought to increase much above average this capability.

Furthermore, an indication about countries may be done when we observe Table 5. It is done comparing PIEESC and pIEESC configurations. Besides being a more perceived strategy, the main countries in economic and political way are present in PIEESC configuration. In a G7 comparison,¹² just Canada has pIEESC configuration.

To corroborate analysis, the percentage of countries considered as high income country by the World Bank that has high share of patent applications by residents (acronym ‘P’) has increased from 62.5% (10 of 16 countries) in 1986–1990 to 85.0% (17 of 20 countries) in 2005–2010 (Table 6). Still, considering 1986–1990 period,

¹² The USA, Germany, Canada, France, Italy, Japan and the UK.

despite the existence of 16 countries classified as high income countries by the World Bank, only 9 were present on PIESC or pIESC configurations. But five of the seven countries outside of these settings had high shares of patent applications by residents. The problems for these nations were related to education (3 countries), infrastructure (1 country) and credit (1 country).

South Korea for instance is an emblematic case, as its catching-up process was a result of a national effort to increase the production of new relevant knowledge.¹³ Its innovative performance was (and is) largely dependent of the learning of organizations in an intensive strategy to improve their competence stocks, which was reflected directly on the nation' economic development. In other words, South Korea is the only country in the sample of these best fit configurations (PIESC and pIESC) who reaches technological catching-up, and it was able to do this with an increase on domestic competence to improve technological appropriability (from 30,2% to 75,9%, an increase of 152,1% on share of patent application by residents).

The arguments and findings pointed out in the previous paragraphs may be seen in a perspective based on assimilation theories (Pack and Westphal 1996; Kim 1997; Nelson and Pack 1999). On this view, the learning domain and the capacity in replicating new knowledge are relevant features that were absorbed by firms (and other innovative agents) in many nations during their catching up processes. This leads to arguments in favor of the need to allow domestic companies to incur copying and imitation strategies.

There are many historical examples about the validity of this argument. The East Asian economic growth during the 80s and 90s was based on imitative strategies in the period of import substitution (Kim and Nelson 2005). The internal capacity of USA companies on assimilating knowledge in chemical industry was achieved under imitation from Germany companies (Mowery and Rosenberg 2005). Chang (2003) shows that during most of the eighteenth and nineteenth centuries, the European economies had used different policies seeking to imitate technologies of its competitors.

The results found in this paper corroborate the need of internal absorption of knowledge at the company level in developing countries. It defines interesting contradiction against the current harmonization of the global intellectual property system established by TRIPs for example (Michalopoulos 2003). As pointed out by Maskus (2000, p.144):

It therefore seems that as incomes and technical capabilities grow to intermediate levels, adaptive innovation emerges, but competition remains focused largely on imitation, so that the bulk of economic and political interests prefer weak protection. As economies mature to higher levels of technological capacity and as demands for high-quality, differentiated products increase, more domestic firms favor effective IPRs. Finally, at the highest income levels, the strength of IPRs shifts up sharply (...) (MASKUS 2000, p. 144).

So, the question that emerges is: is this increase on internal knowledge production (captured by our variable associated with patent) not just maintenance of the status, since it prevents the so necessary process of imitation for developing countries? Thinking in this way, the race to improve internal knowledge production may be just a way to follow the rules of the game, since the TRIPs is given and there is no movement to change it. Limiting the ability of national companies of developing

¹³ Many studies corroborate this point such as Kim (1997) and Laplane and Ferreira (2013).

countries in imitating and appropriating technology from companies of developed countries expresses itself limiting the possibility of a national catching up.

Final Remarks

We showed in this paper that one important ingredient for learning is available knowledge and its multiple uses are likely to generate increasing returns from learning and knowledge accumulation (Marengo et al. 2012). If knowledge is kept in secret or protected by law (with IPRs), other companies are not able to access the main ingredient for learning, thus, in a macro perspective, technological opportunities are reduced.

Recent studies show that in some developing countries, such as the case of Brazil, most of the patents are granted to non-residents. For instance, analysis of patent data issued by the National Institute of Industrial Property (INPI), shows that on average 89.34% (for the period 2000–12) of them were granted to non-residents (Chiarini and Silva 2016; Chiarini et al. 2016). This certainly has important implications for the development process of Brazil: If almost 90% of patents are granted to non-residents, it is likely to inhibit the power of local business innovation, as the cost of getting them is high, with the likely risk of wide-spread exclusion, as these companies do not have the financial means to afford such costs (Tigre et al. 2010). Likewise, we can assure that IPRs on the hands of non-residents impose obstacles to resident imitators in what regards the learning process.

We also considered in this paper that a country's innovative performance is closed linked with industries' capabilities to build new competences through knowledge absorption. Those countries that were able to successfully develop were those that fostered the increase in new knowledge stock, fostered both organizations and individuals learning, and permitted imitation.

By this token, countries can take the path of development through a process of imitation, which leads to having the knowledge necessary to develop other competences. Imitation is possible in countries where there is a low degree of legal protection of IPRs. However, it seems unrealistic to suggest their end. Quoting Machlup (1958, p. 80):

If we did not have a patent system, it would be irresponsible, on the basis of our present knowledge of its economic consequences, to recommend instituting one. But since we have had a patent system for a long time, it would be irresponsible, on the basis of our present knowledge, to recommend abolishing it. This last statement refers to a country such as the USA—not a small country and not a predominantly non-industrial country, where a different weight of argument might well suggest another conclusion.

We tried to show that the protection of ideas and IPRs severely limits the possibility of access to the ideas covered by them and create extra costs for catching-up countries. What we suggest then is that technological competence stock and competence building increase a country's technological opportunity. Companies more competent to absorb knowledge, through reverse engineering for example, are more likely to thrive.

Even considering that IPRs reduce learning possibilities, IPRs (indirectly and imperfectly) indicate the level of technological competence of a country, that is the reason why we opt to use the share of patents deposited by residents as a proxy for

domestic knowledge production. Consequently, after this interpretative framework, we intended to verify the importance of indigenous knowledge production and economic development. For this purpose, we combined information regarding the latter—GDP per capita—and its literatures' well-remarked determinants with the variable 'share of patent applications by residents' (as a proxy of indigenous knowledge production) to attempt the validity of the relationship between the latter and the former in the Qualitative Comparative Analysis technique (QCA). This technique was useful once it does not require the establishment of an economic growth equation in a theoretical level, and because distinct development patterns can be observed, each one being represented by distinct configurations.

The results corroborate our initial proposition about the relevance of domestic knowledge production as an important feature of countries with high level of economic development. Firstly, it could be seen that all countries at the sample are improving their share of patents on residents' hands over the time. The growth was higher than all other explanatory variables, except education level. Secondly, when considering all determinants in QCA technique, the share of patent application by residents is presented as important as all other variables, with exception for "international trade".

Third, despite some nations have reached high levels of economic development without great levels of the share of patent application by residents (configuration pIESC), the usual pathway is the opposite. Even for those nations with pIESC configuration, the increase on knowledge production among periods is far above the average, which points out to an increasing of importance of patents on residents' hands over time. Most high-income countries (considering the World Bank definition) have increased their internal knowledge production. And, last but no less important, the paradigmatic example of South Korea in accessing technological catching-up was achieved with sustained increases on its domestic competence regarding technological appropriability.

These findings points out to the relevance of considering indigenous knowledge production as a strategy to be pursued to economic development as so other features should be. But, acknowledging the increase on domestic knowledge production in countries considered as other configurations, questions associated with the "Red Queen Effect" and relevance of imitation processes are raised. In addition, considering results from Maskus (2000) and Michalopoulos (2003) among others, there is an interesting contradiction against the current harmonization of the global intellectual property system established by TRIPs.

To what extent the increase on internal knowledge production (captured by our variable associated with patent) is not just the maintenance of the status quo, since it prevents the so necessary process of imitation for developing countries? Thinking in this way, the race to improve domestic knowledge production may be just a way to follow the rules of the game, since TRIPs is given and there is no movement to change it. Limiting the ability of national companies of developing countries in imitating and appropriating technology from companies of developed countries limits the possibility of a national catch up.

It would be an interesting research agenda derived from the paper's results, still considering the relationship of internal knowledge production with education and innovation systems, since these two variables presented important growth through time and they are relevant determinants of innovative capacity of a nation.

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