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A CHANGING ROLE FOR UNIVERSITIES IN THE PERIPHERY

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A CHANGING ROLE FOR UNIVERSITIES IN THE PERIPHERY[*]

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SUMÁRIO

RESUMO

Uma pesquisa internacional sobre interações entre firmas e universidades é uma oportunidade para investigar o assunto para além dos países em desenvolvidos. Nesse projeto, que envolve 12 países de três continentes diferentes, África (África do Sul, Nigéria e Uganda), Ásia (Coréia do Sul, China, Índia, Tailândia e Malásia) e América Latina (México, Costa Rica, Argentina e Brazil). Esse artigo trata do arcabouço teórico desenvolvido para lidar com um grupo de países tão variado, com os diferentes níveis dos seus Sistemas Nacionais de Inovação e seus distintos níveis de desenvolvimento. Esse arcabouço deve contribuir para a formulação de políticas públicas para entender o papel das universidades na busca de uma inserção ativa na divisão internacional do trabalho.

Palavras-Chave: interações entre universidades e firmas, sistemas nacionais de inovação, processos de catch up.

ABSTRACT

An international research on interactions between universities and firms is an opportunity to investigate this subject beyond the developed countries. This project involves 12 countries from three continents: Africa (South Africa, Nigeria and Uganda), Asia (South Korea, China, India, Thailand and Malaysia) and Latin America (Mexico, Costa Rica, Argentina and Brazil). This paper introduces a theoretical framework to deal with this broad set of countries, their different levels of NSI formation and their different levels of development. This framework may help public policies to understand the role of universities for a country search for an “active insertion in the international division of labor”

Key Words: interactions between firms and universities, national systems of innovation, catch up processes.

JEL Classification: O30

INTRODUCTION

An international research on interactions between universities and firms - funded by IDRC's RoKS program[1] - is an opportunity to investigate this subject beyond the developed countries. This project involves 12 countries from three continents: Africa (South Africa, Nigeria and Uganda), Asia (South Korea, China, India, Thailand and Malaysia) and Latin America (Mexico, Costa Rica, Argentina and Brazil).

The wealth of information and data gathered by this IDRC-RoKS project is presented by the initial results from Africa (Kruss et al, 2009), Asia (see the special issue of the *Seoul Journal of Economics*, volume 22, number 4, 2009) and Latin America (see the special issue of the *Science and Public Policy*, volume 37, number 7, 2010), and by the background reports summarized by these papers.

The results from this investigation and the discussions within the Catch Up Project led by Richard Nelson support a reflection on how interactions between firms and universities are organized throughout different stages of development and how they change over time. The concept of national systems of innovation organizes the whole research and is the thread that integrates these different countries. How can we understand the diversity of countries that this research involves? A starting point can be to investigate their distribution according to different "regimes of interaction", an approach that evaluates the level of formation of different NSIs, according to available S&T statistics.[2]

This paper introduces a theoretical framework to deal with this broad set of countries, their different levels of NSI formation and their different levels of development. The main motivation of this theoretical framework is a dialogue with the pioneering papers from Klevorick et al (1995) and Cohen et al (2002) that may broaden the subject of interactions between firms and universities beyond the US case or the developed nations.

This paper is organized as follows. The first section describes the main features of these 12 countries regarding the level of their NSIs' formation. The second section presents a question of methodology. The third section introduces the theoretical framework. And the fourth section concludes the paper.

1. STAGES OF FORMATION OF NSIS AND REGIMES OF INTERACTION

Figure 1 shows how diverse and rich is our set of participating countries, since there are countries distributed by the three different "regimes of interaction". Figure 1 displays the per capita scientific and technological production of these 12 countries, measured by the proxies of ISI scientific papers and USPTO patents, for the years of 1974, 1982, 1990, 1998 and 2006.[3] The trajectories of our 12 countries are summarized in Figure 1.[4]

[1] IDRC supported the research in three continents (see http://www.idrc.ca/en/ev-115348-201_103470-1-IDRC_ADM_INFO.html).

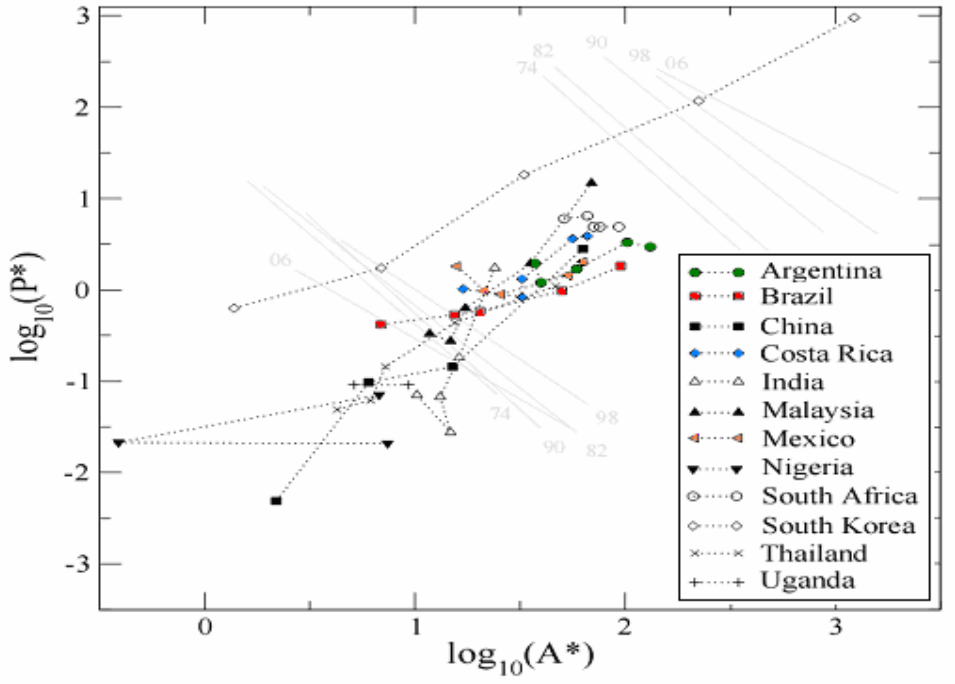
[2] Bernardes et al (2003) suggest these three "regimes of interaction between science and technology". Albuquerque (2004) uses these regimes to investigate Brazil and India.

[3] Ribeiro et al (2006) explain how this Figure is prepared.

[4] Exceptions regarding the years presented in those trajectories are China (data for 1982, 1990, 1998 and 2006), Nigeria (data for 1990, 1998 and 2006) and Uganda (data for 1998 and 2006).

FIGURE 1

Evolution of the *per capita* scientific and technological production for the 12 countries involved in the RoKS Project (1974, 1982, 1990, 1998 and 2006)



Source: Ribeiro et al (2009).

The South Korean trajectory shows a country in the Regime I in 1974, overcoming the threshold between Regimes I and II in 1982, and overcoming the threshold between Regime II and III in 1998, joining the group of developed countries. This trajectory is a successful catching up seen by the lens of science and technology data. South Korea's trajectory also shows that underdevelopment may be overcome.

In 2006 the 12 countries are distributed through all three regimes: Uganda and Nigeria in Regime I, all four Latin American countries, South Africa, India, Malaysia, Thailand, and China in Regime II and South Korea in Regime III. Hence, this project is very representative in regard to different levels of development, since as Ribeiro et al (2006) show, there is a high correlation between the position in the science and technology space (displayed in Figure 1) and GDP per capita (this is the z-axis of a tri-dimensional graph presented by Ribeiro et al, 2006).

This research has the concept of national system of innovation (NSI) as a starting point. There is a qualification about the usefulness of this concept for less-developed countries. These countries must have at least the presence of key components of a NSI to be able to produce USPTO patents and ISI-indexed papers that are presented in Figure 1. Immature NSIs may characterize countries in Regimes I and II (Rapini et al, 2009).Therefore, this research focuses on key institutions of a NSI in formation (on the one hand, universities and public research institutes – PRIs -, on the other hand, firms), and the interactions among them.

The use of the concept of NSI stresses that this research is not about interactions between universities and firms per se, but about a set of institutions and relationships among them embedded in a broader framework – the NSI. By its turn, NSI has a deep (and causal) relationship with development. Thus, the formation of a NSI is a precondition for overcoming underdevelopment.

Since development is a complex and multi-causal process, the stress in the role of NSI for development does not mean any suggestion of a mono-causal approach. On the contrary, this research while focusing in specific building blocks of a NSI, informs a deeper understanding about how the process of university formation is dependent upon other historical and political conditions – nation and state building – that underlie the creation of universities and PRIs. For example, the late onset of universities and PRIs in Latin America seems to be correlated with the Latin American late industrialization (for the Argentine case, see Arza, 2009; for the Brazilian case, see Suzigan et al, 2011).

This argument can be further elaborated to encompass other levels of development.

In the first Catch Up Meeting (Columbia University, May 2005), Professor Robert Evenson put forward a clear relationship between universities (or at least higher education institutions) and the diffusion of Green Revolution Modern Varieties (GRMV). Countries without the beginnings of a university system, or more specifically, countries with "failed National Agricultural Research Systems" (NARS) had achieved no or very limited diffusion of GRMV adoption rates (with consequences upon the pace of their industrialization process) (Evenson, 2005, p. 1 and p. 3). Evenson et al (2003, p. 758) argue that NARS and International Agricultural Research Centers (IARCs) "generally fill complementary roles". Evenson's remarks stress how PRIs are key for the diffusion of available international knowledge, and in the case of GRMV this knowledge is public. Furthermore Evenson mentions a relationship between "failed states" and "failed NARS" (Evenson, 2005, p. 1). Kruss (2009, p. 15) points the large share of international donors for Uganda's universities.

For countries in the Regime II (South Africa and Brazil, for example), one research finding is that existing "points of interaction" have long lasting historical roots: mining sector and PRIs in the South African case (Kruss, 2009; Pogue, 2006), agricultural products, iron and steel and airplanes in the Brazilian case (Suzigan et al, 2011). However, South Africa and Brazil seem to be under the "Red Queen Effect", and probably this is the consequence of persistent income concentration problems that block the emergence of successful "points of interaction" in other knowledge areas and products.

South Korea, in Regime III, is very illustrative of the whole catch up process. According to Lee (2009), "the dynamic evolution of university-industry relations underscores the need to see UIL in an evolving process depending on the stage of economic development of a country" (Lee, 2009, p. 6). This interpretation informs a reading of Kim (1997) that indicates how the South Korean government took the initiative to create PRIs since 1966 (Kim, 1997, p. 84), ahead of any demand from existing firms, and how this type of state initiative was repeated in industries such as electronics (p. 207), and computers and semiconductors (p. 214 and p. 228). These South Korean state initiatives should be interpreted as part of a more general economic framework that, according to Amsden (1989), the South Korean state built to discipline both labor and capital.

These very summarized comments help to differentiate clearly at least three patterns of universities and PRIs formation: 1) failed states lead to failed universities/PRIs; 2) states captured by elites (Brazil, South Africa under apartheid) or states that only "discipline labor" lead to limited "islands of excellence"; 3) states with capabilities to indicate strategic areas for private investment have led to dynamic creation of PRIs and have guided their interaction with firms by way of industrial policies, leading to the overcoming of underdevelopment.

This differentiation, very introductory but illustrative of more general trends (deeper socio-historical currents) highlights how complex is the study of universities and their interactions. Indeed, there is a great challenge that Latin American countries face, after a set of dictatorial governments (that failed to overcome underdevelopment): how democratic and participative processes may improve informed decisions about complex subjects as allocation of resources for science and technology. This would add a new building block in the framework of NSI: the relationship between democratic processes, public policies and the maturing of NSIs.

Finally, this research (and its findings) has stimulated us to rephrase our initial hypothesis about the small significance of universities for less-developed countries. During this research we learned how to find and evaluate interactions between universities, PRIs and firms and society. The end result is an improvement in our understanding of the relevance of universities in all stages of development and to identify the lack of universities and/or their limits in terms of size and quality as constraining factors for development.

2. A QUESTION ABOUT METHODOLOGY

This research has used different investigation tools to deal with our subject: interpretations of available data (patents, papers), surveys (firms, universities), case studies of selected points of interaction, and historical studies. This combination of different research tools seems to be very helpful, since what one research instrument can not capture, another can. Furthermore, one instrument may complement other.

Each instrument has its "blind spot".

The surveys are very informative (see papers about them), but may provide a distorted image of the overall picture. For Latin American countries, for example, they are basis for the elaboration of matrices of industrial sectors and S&E fields that show "spots of interaction" - weak and not well distributed "points of interaction" (see Latin American summary of findings for Cape Town's Workshop). However, when historical studies focus these points of interaction, they unveil the history behind each of those points and how long-lasting were those interactions (Suzigan et al, 2011). These historical studies also show how those sometimes scarce points of interaction are important for the economy as a whole.

The combined interpretation of results coming from different research tools informs a re-reading of our survey results, highlighting the importance of those points and how they matter for the economy.

Historical studies show the importance of topics such as the process of state and nation building and social inequality to understand the social constraints for university creation and growth. University creation may be seen as an anti-elitist policy, and as such a policy goal to be confronted by existing elites (educated or uneducated).

Beyond the research tools used by our Project, there is also information provided by the lack of data, by difficulties and obstacles to surveys application, by the openness of firms and universities to our investigation. The conversations and negotiations between the different national teams about our research tools are also informative.

3. THEORETICAL BACKGROUND

Klevorick et al (1995) and Cohen et al (2002) provide a good starting point for discussions about universities, firms and interactions since they show a snapshot of the state of such interactions in a developed country. Those papers were important references for the beginning of our research investigation (see Rapini et al, 2009).

To introduce a discussion about interactions between universities and firms and development, the snapshot captured by Klevorick et al (1995) and Cohen et al (2002) may be interpreted as a sort of a "provisional end result" of a long historical development.

"Provisional", because technological development has not ended – for instance, in adapting the questionnaire of the pioneering Yale and Carnegie Mellon Surveys we included a new source of interaction: the internet. "End result" because there is history underlying each "source of information" and each "channel of knowledge".

The picture described by Cohen et al (2002) may be an empirical representation of what a large literature on interactions between science and technology has put forward between the 1970s and the 1990s. Our reading of this literature and how we have dealt with it in our research agenda is reviewed in previous works: Bernardes et al, 2003 and Rapini et al, 2009.

Cohen et al (2002) helped our research team to organize our investigation because their paper pointed three key issues for our pervious investigations (Rapini et al, 2002) and for our RoKS research project (Dutrénit et al, 2007): 1) how different science and engineering fields are important for different industrial sectors; 2) what are the most important sources of information for firms' innovation; 3) through what channels of knowledge flows do firms and universities communicate.

However, the theoretical background that supported the investigation of interactions between universities and firms within the United States' NSI is not enough or adequate to the non-developed world. The most important reason for this limitation is that in the United States' NSI (and in other mature NSIs) there are strong actors working: on the one hand large and top level universities (Rosenberg, 2000); on the other hand, a set of dynamic multidivisional and multinational firms with capabilities to monitor and to use science and engineering fields and to interact with those universities (Chandler, 1990). Indeed, those actors are a result of a long term historical process, as both Rosenberg and Chandler point out in their books.

To deal with underdevelopment (according to Celso Furtado's concept, see Furtado 1986 and 1987) and with catching up countries like South Korea a dynamic framework is necessary. Since universities, firms and the interaction among them are part of the conceptual framework of NSI (Freeman, 1988), this dynamic framework must deal with the specificities of NSIs at the periphery (Albuquerque, 1999 and 2007). These specificities include the existence, nature, size and quality of universities on the one hand, and the existence, nature, size, capability, diversification and variety of firms on the other hand. Therefore, it is necessary to study both the evolution of universities and public research institutes and the evolution of firms. The interplay and interactions between universities and firms change over time, depending on the stage of development of both actors and the links (and their intensity) among them. Historically there is a dynamic feedback process between these two formation processes (of universities and firms) that generates a variety of forms of interaction between universities and firms. Eun et all (2006) show how this process unfold in East Asian catch up processes.

3.1. Connecting the Periphery to Technological Revolutions at the Center: universities as Antennas

The first building block of the specificities of interactions at the periphery is the role of universities as "antennas" of science and technology produced at the center of the capitalist system.

The nature of technological progress in capitalism was discussed by Marx (1867), showing how the permanent revolution of technological basis is a key factor of capitalism. Later, Schumpeter (1939), Mandel (1974) and Freeman (1982) have shown how technological revolutions through long waves of capitalism development shape and reshape the structures of capitalist economy. The literature on interactions between science and technology at developed countries could be read as explaining how these technological revolutions are generated at the center. Those technological revolutions again and again generated at the center of capitalism are diffused throughout the whole world and impact the countries at the periphery of the capitalist system (Furtado, 1986). Therefore, the structuralist polarity between center and periphery, suggested by Prebisch, is one important starting point for our theoretical background (see Furtado, 1986).

This standpoint illuminates where are we investigating the interactions between universities and firms: at the periphery, a part of the world where technological progress generated at the center impacts and replaces the position of countries in the international division of labor.[5] The impacts on the periphery of the waves of capitalist development change and reshape the challenges and opportunities for catching up. This dynamic international technological framework is the context in which the universities at the periphery establish their first role: universities at the periphery might be an important channel to absorb knowledge generated abroad, to absorb knowledge from the center of technological dynamics.

[5] For an attempt to articulate the process of technological revolutions at the center and its impacts on a peripheral country like Brazil over time, see Albuquerque (2007, section 2.2).

This simplified dynamic international technological framework implies that the tasks of universities and firms related to knowledge absorption are ever changing. As the "Red Queen effect" suggests, sometimes it takes a lot of effort just to "stay in the same place, just to preserve the existing technological gap vis-à-vis developed countries" (Ribeiro et al, 2006).

While the overcoming of underdevelopment is possible and feasible, as South Korea has shown (Furtado, 1992), it is a great challenge. And the overcoming of underdevelopment depends strongly on universities, firms and interactions among them.

3.2. Universities and PRIs: important since the early stages of development

Universities and PRIs are one of the first channels to connect one country at the periphery to the international flows of science and technology.[6] The first universities and PRIs in less-developed countries are created with foreign teachers and/or native students that graduated abroad. As Richard Nelson has put forward, "in countries behind the frontier universities often are key institutions in the building of capabilities in sciences and technologies because they provide a home, a stopping off point, and a source of the transnational flow of people in science and technology" (personal communication with the authors, 3 August 2009).

The decision to create local universities and local PRIs depend upon the level of nation and state building. The date of creation of the first (relevant) universities and PRIs therefore is an important information. Latin American countries, for instance, have in common a late onset of their universities and PRIs (19th Century),] highly correlated with national independence processes and initial organization of national and public finances.

Late development, by definition, means high levels of poverty, inequality, strong social problems such as slavery, ethnic segregation, and colonization. Therefore, since their formation, local universities and PRIs are confronted with great challenges, which determine a "dual role" for them, for they must, on the one hand, keep in touch with scientific and technological development a the center while, on the other hand, they will face various problems and issues (diseases, soils, plant varieties, geological and climate conditions) that need specific investigations and might generate new scientific knowledge.

Furthermore, there are various tasks to be performed by universities/PRIs: teaching, training of human resources for public administration (specially at the beginning of the nation building process) and for creating the first firms (part of them state-owned: infrastructure, key mining and manufacturing sectors), diverse problem solving tasks and eventually (in the beginning) truly original scientific research (specially in agriculture and health).

Later, during the initial industrialization process of late comers, it seems to be an empirical regularity a sort of wave of institutional formation, with new PRIs and universities (at least faculties) that may help to solve new (and more complex) problems. In the Brazilian case we identify a combination of late industrialization and late beginning of local scientific institutions. However, both events are related with deep structural changes in society, which are consequence of important

[6] Other forms of early connections to developed countries are travelers, traders, and study abroad.

political changes. Therefore there is not any automatic mechanism operating, a mechanism that would push the process of institutional building ahead. Given the potential anti-elitist nature of the process of university creation and expansion, social movements are also an important factor to stimulate the formation of new institutions.

The process of university formation is multifarious, therefore neither determinist nor automatic. There may be demands to solve societal needs (to fight diseases and epidemics),there may be demands from organized agricultural producers to face plagues or bugs that hurt harvests, from mining sectors to up-grade mining techniques, there may be demands from governments to provide tests for infrastructure building. But there may be also institutional building ahead of the demand (after some state initiatives) that later should foster the creation of new industrial sectors.

No matter what was the driving force for institutional building, once created universities and PRIs trigger a new process that has new actors, with new demands and opening new opportunities for the local economy and society. One important feature of this new dynamics is the attempt to preserve links with the evolving S&T international environment.

In this new dynamics, the enlargement of universities and PRIs and consequent diversification (so important, according to Figure 1) is itself a process with social resistance and not easy. Size, diversity and quality of universities depend upon various social variables like the reduction of illiteracy, universal access to basic and secondary schools, which are dependent upon other social variables such as income distribution and welfare conditions. Social constraints to university development are, therefore, causes of limitations in the role of universities for development – underlying causes of the "spots of interaction" identified in countries like Brazil.

As universities and PRIs grow, their dual role becomes more complex. On the one hand, they must perform their role as "antenna" for local society and economy in a broader range of S&E fields, since these fields grow in number and scientific complexity at the center. On the other hand, local demands and local research questions grow in size and complexity. This role as "antenna" changes over time, with new tasks put forward by technological revolutions at the center. This role exists throughout all development phases: compare the role of NARS to diffuse GRMV (Evenson, 2003) and the creation of the Korean Institute for Electronic Technology (KIET), in South Korea (Kim, 1997, p. 214) to help local (large) firms to enter the computer and semiconductors industries.

In sum, over time the evolution of local universities means that their roles become more diverse (teaching in new areas, research in various directions, following diverse motivations, demands for advice for public policy and public health). This point summarizes what Eun et al (2006) call the universities capabilities.

This role as antenna defines a key position in society and economy: universities and PRIs should perform a structural role for the technological upgrading of peripheral countries. This specific role leads to actions "ahead of the demand", and the consequent mismatching between new areas and existing industrial capabilities.

Finally, there is a specific dynamics between universities and PRIs: PRIs may be short cuts for overcoming structural debilities with universities, PRIs may be starting points of formation of S&T institutions (this is the case in Brazil, for instance), later changing their roles as universities develop, and they may be instruments to articulate industrial policies with S&T policies.

3.3. Firms, Farmers and Society: multiple sources of diferent demands on universities

Even in least developed stages there are demands on universities and PRIs to transfer knowledge publicly available in international networks to the country. Evenson (2005) shows how available public knowledge on GRMV could not be transferred to a set of countries given the lack of National Agricultural Research Systems (NARS). Health needs for poor populations cannot be answered given the scarcity of health professionals, mainly university-trained physicians.

In early stages of development, agricultural and health issues are there as unattended demands on universities and PRIs – and this may be present in less developed regions within a large and uneven country as Brazil. This remark is important because during our investigation we have dealt again and again with problems regarding the focus on university-industry linkages. Indeed, more developed countries (and more developed regions within a large and uneven country) also have these two kinds of demands presented to universities and PRIs that go beyond the strictly industrial dimension. Therefore, universities and PRIs should preserve this sort of broader relationship and interaction with society throughout all phases of development.

Firms depend upon universities for trained human resources (engineers, chemists, biologists, software professionals etc). Today it seems to be impossible to create new firms without any university-trained professionals in various industrial sectors and probably beyond a threshold size of the firm (given its engineering and managerial complexities). This is one long-lasting relationship between firms and universities, which is preserved throughout all development phases. Probably this relationship is overlooked by traditional industrial economics field.

As long as industrialization advances, new demands are presented to universities and PRIs, from tests to more complex problem-solving tasks and adaptation of more complex foreign technologies. There may be a sort of self-organizing formation process of new sorts of interactions that unfold as industrialization processes grow.

Eun et al (2006) emphasize the absorptive capabilities of firms and a specific dynamics that their growth determines. As one persistent empirical regularity, the growth of firms capabilities is correlated to the growth of the importance of universities to firms. Dynamically, this means that as firms' capabilities increase, new demands on universities and PRIs emerge.

New firms are created all the time. What kind of firms are created and how long will them survive depends on several factors. Studies on birth, survival, mortality and growth of firms would be important here. The process of new firms creation is also highly dependent on other social and political conditions such as access to credit (public and/or private), educational conditions (the educational level of firms' founders matter, because in certain industrial sectors university training may be necessary to create a firm), no existence of social, colonial or ethnic constraint (in Brazil, the Portuguese prohibited manufacturing activities until 1808, in South Africa during apartheid "it was illegal for Africans to head their own enterprises or to engage in manufacturing activities", according to Terreblanche, 2002, p. 379). This process of firm creation, as the process of universities formation, is also dependent upon broader social conditions. Gerschenkron (1952) has shown that for latecomers industrialization is not an automatic process, on the contrary, it is a process highly dependent upon institutional innovations such as banks (industrial and development banks) and state initiatives for firm creation in key sectors.

The vitality, sectoral nature and spread of this process of new firms' creation, in turn, define the nature, intensity and importance of demands on universities and PRIs. Therefore, industrial policies are very important for this process as a whole.

Finally, transnational corporations (TNCs) impact the whole process, since they are a historical product of capitalist development at the center and may (or may not, depending on industrial and public policies) help or constrain industrial development at the periphery (Amsden, 2001). TNCs establish new channels of knowledge flows. These firms have links with universities at their home countries: the firms' samples investigated by Klevorick et al (1995) and Cohen et al (2002) contain TNCs whose headquarters are in the US. Their subsidiaries at peripheral countries may not have any links with local universities, but they have "indirect" links with foreign universities. Furthermore, TNCs may define a hierarchical "internal division of labor" that combines contacts with local and foreign universities. Eventually, TNCs may establish links directly with local universities without local subsidiaries. In sum, TNCs must be taken into account regarding diverse and new channels of knowledge flow, determining new specificities of interactions at the periphery.

In an opposite direction, local firms may grow in size and capabilities and have new demands on local universities that can not be answered by them. Thus, these local firms may establish direct contacts with foreign universities, both for complex problem solving and for technological upgrading.

3.4. Interactions and Changes over Time: matches and mismatches as structural phenomenon

As suggested by Eun et al (2006), to investigate interactions and their dynamics over time it is necessary to evaluate both the capabilities of universities and capabilities of firms. As Figure I shows, size of universities and PRIs matter, because critical mass thresholds must be overcome. Furthermore, Figure I may have a qualitative interpretation: for instance, the quantitative steps taken by South Korea between 1974 and 2006, jumping from Regime I to Regime III, are related to qualitative changes related to entering in new industries, especially in Information and Communication Technologies (see Kim, 1997).

These basic factors underlie the multifarious interactions between the two agents (see section III) that our research project has described.

The workings of the channels of knowledge flow investigated by Cohen et al (2002) have a historical evolution. On the one hand, there is a process of change of universities capabilities. Initially, universities and PRIs may provide human resources, testing, and simple problem solving (consultancy, technical assistance), later universities and PRIs become better equipped and their laboratories may be used by local firms. Finally, they take one step further and undertake research activities that substitute and/or complement firms' R&D. On the other hand, there is a process of change in firms' capabilities. Initially firms may only use university-trained human resources, later they may look for universities and PRIs to solve technical problems, and as these problems become more complex, research issues may arise and R&D joint projects become part of the agenda.

This double-sided metamorphosis is well illustrated by the South Korean experience. The Korean Institute of Electronics Technology, created to help firms to have access to computer and semiconductor technologies, provided information for firms entering these technology sectors while they improved their internal capabilities. As these firms' internal capabilities increased, they became able to buy this institute (Kim, 1997, p. 214 and p. 228).

An important finding of this Project is the relevance of universities and PRIs even to low-tech sectors. This importance may be illustrated by the mining sector: historically, the cases of South Africa (Pogue, 2006) and Brazil (Carvalho, 2002) show how faculties and universities were important to bring updated knowledge from developed countries to existing local firms, in the case of South Africa, or to create new firms, in the case of Brazil. Our surveys did find both in South Africa and Brazil points of interaction between mining sector and S&E fields such as mining engineering, materials engineering and geosciences. These points of interaction have deep historical roots.

There is a learning process, both from the firms' side and from the universities' side, once the interactions begin. These relationships have a proper logic, with a sort of autonomous process. This internal dynamics of each point of interaction may involve shared knowledge, mutual trust, transfer of personnel between the two actors, a better understanding of each other - a sort of logic that Williamson (1985) evaluates using the transaction costs framework. Of course, the history of these interactions may be short lived or last longer. Therefore they may change over time, becoming more efficient and more productive for both sides. What our surveys capture are snapshots of interactions that have history behind them (that is unveiled by case studies of points of interactions).

Universities and PRIs must initially answer to non-industrial demands: education necessary for a nation building process, agriculture and health. These roles never disappear, while new ones always are created. As industrialization begins, it puts forward new demands. Old and new tasks are combined and must be answered by local universities (there are different layers of demands, as new demands are added and the old ones are reshaped and restructured). Therefore, university-industry links (UILs) are just part of the overall functions of universities, even in the interactive domain.

The diversity of forms of interactions between universities and firms may be further illustrated by the Chinese experience: as Eun (2005) has shown, academic-run enterprises and university-run enterprises (AREs and UREs) are specific forms of relationship in China. Eun et al (2006) suggest that this mode of interaction is specific for a context in which academia and universities have stronger capabilities than firms. Financial conditions matter here, since universities have access to state and to township and village resources that may fund new firms that they create - but they do not spun-off. This Chinese specificity, as Eun (2005) explains, has historical roots that can be traced to 1949, the foundation of People's Republic of China. Eun mentions "three major peaks of ARE development", during the Great Leap Forward, during the Cultural Revolution and after Deng's reforms (especially the S&T reforms).

These remarks suggest that the matching between universities and firms are exceptions. The norm, especially if there is a catching up process progressing, is the mismatching between universities and firms.

First, as discussed earlier, the peripheral condition assigns to universities and PRIs the role of "antenna". As "antennas", universities and PRIs have access to available international knowledge that is not available locally. Therefore, at the periphery universities and PRIs provide technological opportunities to existing and new firms. This form of technological opportunity through those antennas is another specific feature of technological progress at the periphery (compare this form of technological opportunity with those discussed by Dosi, 1988). These technological opportunities provided by local universities and PRIs may be wasted or not, depending of other conditions, including industrial policies. Over time, even when universities and PRIs are doing their job properly, mismatches with industries may take place.

Second, new economic sectors in peripheral countries may be created after first movements taken by universities and PRIs. Thus, at least temporarily, there may be mismatches between the two actors.

Third, as in the center, in the periphery there are structural differences in the roles of universities and PRIs and firms, consequence of a division of labor within the NSI. These differences are translated in problems of timing, goals and points of view. These problems are perceived by the actors as mismatches - and are well captured by our surveys.

Fourth, local dynamic firms may present demands that local universities cannot answer in the short term. This mismatch may stimulate local universities to find new connections with foreign universities and to upgrade their teaching and research capabilities. But this mismatch may push local firms to have direct contacts with foreign universities. Later these contacts may have spill over effects on both local firms and local universities.

Fifth, as in developed countries, there are, from time to time, conflicts regarding the role of universities and public research institutes regarding issues like the nature of research to be undertaken (basic, applied, a combination of both) and the forms of relationship with firms and private sector. Those conflicts may be seen as part of the efforts to adapt institutions to new tasks and new challenges put forward by the development process.[7]

There is a broad co-evolutionary process that involves matches and mismatches between universities and firms over time, a co-evolutionary process that is subjected to structural changes, therefore it is not a linear or smooth long term process.

3.5. Structural Changes and Interactions in Historical Perspective

The remarks about universities and PRIs (sub-section II.2) and firms (sub-section II.3) have highlighted how social and political factors matter for their formation and growth. Therefore, the whole process is neither a smooth process nor only a quantitative growth. On the contrary, those processes are dependent on structural changes that overcome constraints and open new avenues for institutional formation and innovation. Examples of landmarks in those processes are national independence, abolition of slavery and ethnic segregation, industrialization, democratization, reformist movements for universal education. "Waves of institutional formation" seem to be correlated with those landmarks events.

[7] Prof. Richard Nelson highlighted this point in his comments to an earlier version.

The non-linearity of those processes, given the peripheral condition of the countries involved (with the exception of post-1990s South Korea) is also determined by the uncertain pace of technological revolutions at the center. Given these technological revolutions, the whole university system must be readapted again and again, otherwise the technological gap vis-à-vis developed countries may widen. Technological revolutions at the center determine another structural feature of interactions at the periphery: the tasks of the educational system increases, since old and persistent unsolved issues (such as illiteracy and communicable diseases) now must be tackled together with new issues (such as access to computers and internet and teaching activities in new S&E fields).

The nature of the whole process is related to structural changes, following the approach of structuralist school (Furtado, 1986): advances from one phase to another are related and caused by structural changes.

4. CONCLUDING REMARKS

The wealth of empirical findings of this paper goes beyond the discussion of this paper, but the resulting overall picture is much more complex than we thought at the beginning of our research. A careful reading of Kruss (2009) and the special issues of the *Seoul Journal of Economics* (volume 22, number 4, 2009) and of the *Science and Public Policy* (volume 37, number 7, 2010) shows a myriad of types and cases of interaction between universities, firms and society. It is not the objective of this paper to list them, but it is noteworthy to stress that the theoretical framework suggested by this paper is based on an initial visualization of those variegated types and cases.

Those types and cases inform findings that are against conventional wisdom. There are five that may be mentioned:

1) universities matter for development, for industrial development, since the very early stages of development;
2) in immature NSIs (especially for those countries in the Regime II) the contributions of universities are more advanced than consultancy and tests (there are R&D contracts, and joint R&D projects): heterogeneity is a consequence of this more complex scenario;
3) interaction with firms may enhance the academic capabilities of university research groups;
4) universities and PRIs are important to industries even in low-tech and medium-tech sectors;
5) the investigation of historical roots of existing “points of interaction” in countries in Regime II (so far we have evidence for the cases of Brazil and South Africa) shows how these successful cases where built in a long lasting historical process – a corollary of this finding is the insight that behind each successful point of interaction there is a university and/or a PRI;

Four basic conclusions can be drawn from the research and the suggested theoretical framework.

First, regarding the general contribution of universities for development: a) universities and PRIs matter for development, and it seems that this role has been underestimated; b) this important role changes according to the country's level of development, in other words, universities always matter, but they matter in different ways as development advances; c) the contributions of local universities and PRIs increase as development advances, because there are new demands from local firms and local society and also given the growth of scientific content of technologies over time – at the center; d) over time, and across different development stages, there are changes in the number and relative importance of modes of interaction, S&E fields and economic sectors.

Second, throughout diverse levels of development there is the possibility (and also the necessity) of formation of universities and PRIs "ahead of the demand". In other words, in the development process first movements may be taken by universities and PRIs. Therefore, mismatches and disconnections may be part of the general process of overcoming underdevelopment.

Third, heterogeneity is a structural feature of immature NSIs, since they must always deal both with new tasks coming from abroad (and one important role of universities at the periphery is to work as "antennas" for foreign knowledge) and with old unsolved issues related to underdevelopment. This might imply that universities in less-developed countries may be prone to a sort of institutional overload, for they must perform multiple tasks in an environment of scarce resources.

Fourth, TNCs introduce complex international flows and interactions. They are important in local NSIs (see Brazil, where almost half of all industrial R&D is performed by TNCs' subsidiaries). This demonstrates that the structuralist division between center and periphery is still working. Furthermore, TNCs introduce another international channel of knowledge flow (besides universities and PRIs with their international networks) that may connect foreign universities and local subsidiaries through the TNCs headquarters. Additionally, local flows of knowledge between TNCs" subsidiaries and local universities and PRIs are defined and decided at the TNC headquarters (at least partially, with strategic decisions). Finally, TNCs may use knowledge generated in less-developed countries even without having a subsidiary there (direct international contacts from abroad, acquisitions of new firms that spun off from universities).[8]

This IDRC research may have important contributions for the improving the elaboration on NSIs: 1) findings and information to improve a dynamic approach to NSIs (changes throughout different levels of development); 2) advances for understanding of underdeveloped countries; 3) the role of universities during catch up; 4) a better understanding of how firms depend upon universities; 5) findings to discuss the very start of the process of NSI formation (and how important is the role of universities since the beginning); 6) importance to include other actors beyond firms to understand the beginnings of formation of NSIs; 7) all findings related to our understanding of universities, firms and interactions enrich the NSI concept (see topic III); 8) the necessity to improve our understanding about the influence of social and political factors on the formation processes of NSI; 9) how inequality impacts the process of NSI formation, working as an important constraining factor for development.

[8] One non-intentional by-product of this IDRC Project is the involvement in the Project INGINEUS (see www.ingineus.eu), with a focus on global interactions between firms and universities, based on global innovation networks driven by TNCs. Britto et al (2011) suggest a framework that identifies these international flows of knowledge – and the roles of TNCs and NSIs.

Finally, related to the elaboration on NSIs, the research provides four reflections on public policies:

1) regarding the so-called entrepreneurial universities: this is a misleading concept, since, on the one hand there are multiple roles for universities (not only a role for firms-formation or to substituting firms in some of their roles), and, on the other hand, universities have interactions with a large array of social and economic actors (they are not only the firms);
2) regarding the roles and functions of universities: some of them are inherited from previous phases and can not be thrown away, other unfold as technological revolutions happen; these functions places interactions with firms as one of these functions, and they may be performed by a myriad of channels – which, by their turn, change over time, as new phases of development are reached;
3) regarding the role of universities for development, it is necessary to undo a very general – although implicit - underestimation of the role of universities for development (this topic may be enriched by illustration of how universities and PRIs matter for each level of development, stressing the causality that runs from universities to development) – especially in the early stages of development;
4) growth of universities and PRIs (size, diversification and quality) is necessary to reach CRITICAL MASS and impact (more) development;

In sum, this research may help public policies to understand the role of universities in searching for an "active insertion in the international division of labor": combination between waves of institutional formation (universities and PRIs), well-informed industrial policies (to support new firms formation and stimulate entry in key sectors) and the combination between industrial policies and S&T policies.

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