

# Introduction

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In 2006, the International Development Research Centre (IDRC) of Canada opened a competition on “searching for paths to support the changing role of universities in the South.” This competition provided an opportunity for collaboration between research teams from 12 different countries from three continents. The objective was to fill the gap in knowledge about interactions between firms, universities, and research institutes at the periphery.

Universities, research institutes, and firms are key parts of a National System of Innovation (NSI). The interactions between these key components of the NSI are starting points for a dynamic interpretation of the importance, role, and nature of science and technology. The comparative study published by Nelson (1993) is a product of previous work by Christopher Freeman, Bengt-Åke Lundvall, and Richard Nelson (see Dosi et al. 1988, Part V). Nelson and Rosenberg (1993) summarized the concept of an NSI and set the framework of the comparative study. They stressed that the “intertwining of science and technology” (p. 5) was a complex feedback process that resulted in mutual positive feedback between science and technology – “science as leader and follower” (p. 6). Nelson and Rosenberg (1993, pp. 9–13) also present “the major institutional actors,” which are “firms and industrial research laboratories” and “other institutional actors” – universities and public laboratories. Those lessons shaped our initial views: investigations of interactions between firms, universities, and public laboratories were now seen as investigations of NSIs – zooming in on specific but important components.

Interactions between universities, research institutes, and firms have been deeply investigated within and outside the NSI framework. Three path-breaking papers that looked at these interactions in the United States are Klevorick et al. (1995), Narin et al. (1997), and Cohen et al. (2002). Before 2005, the focus had been on developed countries.

The IDRC-sponsored tri-continent research was an opportunity to broaden the perspectives of investigations on interactions between firms,

universities, and public research institutes – our 12 countries provide enough diversity and variety to include the “South” in the agenda of this important subject.

## TWELVE COUNTRIES: DIFFERENT POSITIONS AND TRAJECTORIES

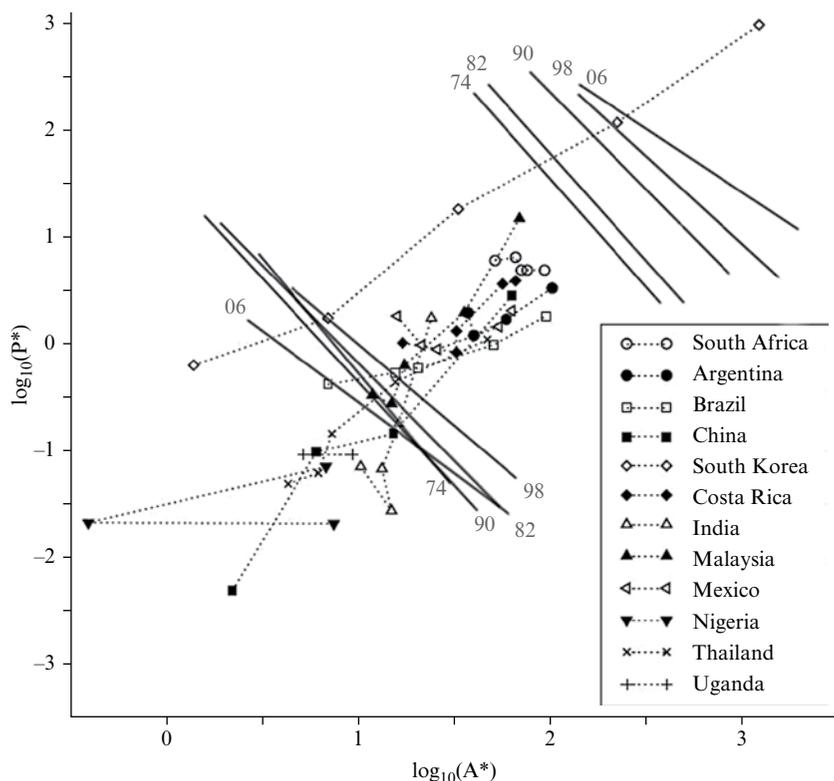
To show where our 12 countries are located in the international arena and how they are moving within it, we chose statistics that are closest to our research subject: patents and scientific papers (Moed et al. 2004). In general, patents are a proxy for technological production, mainly a task of firms, and scientific papers are a proxy for scientific production, one of the functions of universities and public research institutes. Firms do produce scientific papers and universities patents, but those are not their main roles. Statistics on patents and scientific papers are correlated with the wealth of nations – gross domestic product (GDP) per capita in particular (Dosi et al. 1994). The simple juxtaposition of these statistics may provide hints about interaction between science and technology.

Statistics on patents and scientific papers are easily available, and it is possible to build intertemporal comparisons between different countries. Figure I.1 summarizes where our countries are and how they are moving. Based on previous research (Ribeiro et al. 2006), this figure illustrates two important concepts: “regimes of interaction” and “moving thresholds.”

Regimes of interaction is a concept derived from an empirical investigation based on United States Patent and Trademark Office (USPTO) patents and scientific papers indexed by the Institute for Scientific Information (ISI). When all countries of the world are placed on one graph, with their science and technology production per million inhabitants, they cluster in three groups. Those clusters offer an initial reference for the correlation between science and technology: in the first cluster, countries with low technology production also have a low scientific production. At the other extreme, countries in the third cluster have both a high technology production and a high scientific production. If we add GDP per capita to this graph, the lowest GDPs per capita are in the first cluster and the highest are in the third. After the three groups of countries are defined, we can draw two lines: boundaries between the first and second groups and between the second and third groups. Each of those clusters corresponds to one regime of interaction. The limits between them are thresholds. Those thresholds must be overcome as countries evolve from one regime of interaction toward the next.

The second concept is related to those thresholds. When we compare the distribution of the three regimes of interaction over time, it is clear that their thresholds move. As scientific and technological production grows, especially in the leading countries (regime of interaction III), the thresholds move up. This means that, as time goes by, the scientific and technological challenges to the countries at the periphery (regimes of interaction I and II) also increase.

Figure I.1 summarizes information from our 12 countries. The horizontal axis is scientific production ( $A^*$  – ISI-indexed papers per million inhabitants), and the vertical axis is technological production ( $P^*$  – USPTO



Note:  $A^*$ : ISI-indexed scientific articles per million inhabitants;  $P^*$ : USPTO patents per million inhabitants (Ribeiro et al. 2009).

Figure I.1 Distribution of the 12 countries in the RoKS project by the three regimes of interaction and the moving thresholds between those "regimes" (1974, 1982, 1990, 1998, and 2006)

patents per million inhabitants). We have data for 1974, 1982, 1990, 1998, and 2006.

Figure I.1 also shows the moving thresholds: the lines in the upper-right part of the figure represent the thresholds between regime of interaction III (in the upper-right part beyond those lines) and regime of interaction II (in the middle of the graph). The dynamics of those thresholds are seen in the systematic upward movement of those thresholds from 1974 to 2006. Figure I.1 also shows the thresholds between regimes of interaction I and II (this is the lower-left part of the graph), which have more erratic movements.<sup>1</sup>

The trajectories of the 12 countries show the diversity and richness of this set of countries (Figure I.1).<sup>2</sup> In 2006, these countries were distributed over the three different regimes of interaction and over time they showed different trajectories.

Figure I.1 shows the distribution of our 12 countries throughout the three “regimes of interaction.” In 2006, the 12 countries were distributed through all three regimes: Uganda and Nigeria in regime of interaction I; all four Latin American countries, South Africa, India, Malaysia, Thailand, and China, in regime of interaction II; and South Korea in regime of interaction III. Ribeiro et al. (2006) showed that there is a high correlation between the position in the science-and-technology space (Figure I.1) and GDP per capita – this is the z-axis of a tri-dimensional graph presented by Ribeiro et al. (2006). Therefore, our 12 countries are very representative of different levels of development.

Figure I.1 also displays differences among the trajectories of our 12 countries. First, there is the South Korean trajectory. South Korea was in regime of interaction I in 1974, overcame the threshold between regimes of interaction I and II in 1982, and overcame the threshold between regimes of interaction II and III in 1998 to join the group of developed countries. This is the trajectory of a successful catch up – countries may leave the periphery, overcome underdevelopment, and join the centre of the capitalist economy. This trajectory shows that the peripheral condition is surmountable. The process of overcoming underdevelopment features growth in technological and scientific production, or maturation of NSIs. Improvements in the interaction between science and technology, or between universities, research institutes, and firms must improve over time. According to Keun Lee, “the dynamic evolution of university–industry relations [links]

<sup>1</sup> The clustering techniques and the method for defining the thresholds between these groups are presented by Ribeiro et al. (2006).

<sup>2</sup> Exceptions regarding the years presented in these trajectories are China (data for 1982, 1990, 1998, and 2006), Nigeria (data for 1990, 1998, and 2006), and Uganda (data for 1998 and 2006).

underscores the need to see UIL in an evolving process depending on the stage of economic development of a country” (Lee 2009, p. 6).

Second, there is the Chinese trajectory. In 1982, China was in regime of interaction I, but by 2006 China had jumped to regime of interaction II – in a position well ahead of other countries that were earlier in that “regime.”

Third, there is a Latin American trajectory. Mexico, Costa Rica, Argentina, and Brazil have been in regime of interaction II since 1982, and they still are there. If we take Brazil as a representative Latin American country, it has improved its scientific and technological production – there is a correlation between both improvements. However, those improvements have only preserved its position relative to the moving thresholds to the regime of interaction III. Similar to other countries in regime of interaction II, Brazil is running in the science and technology (S&T) international arena to stay in the same place relative to the moving threshold – this is a Red Queen Effect.<sup>3</sup> South Africa has been part of regime of interaction II since 1974, and also appears to be under the curse of this “Red Queen Effect.”

Figure I.1 and its interpretation suggest that those three regimes of interaction may differ in nature, in the direction of flows, and in the intensity of positive feedback between science and technology. The RoKS project was a terrific opportunity to look closely at these channels and flows across our 12 countries.

## ONE COMMON QUESTION, DIFFERENT APPROACHES

In 2007, this research began with a common question for all research projects: How and why do relationships between universities and public laboratories and firms differ across countries and regions at different stages of development, and across sectors? What did our research teams have in common when we started our tri-continent research? We did not have a general theoretical framework covering the interactions between firms, universities, and research institutes, but we did share several ideas.

First, there was a common perception about the importance of these interactions to understand the NSIs in developing economies. The use of the concept of NSIs stressed that our research was not about interactions

<sup>3</sup> The Red Queen Effect was a metaphor used by Van Valen (1973): regardless of how well a species adapts to its current environment, it must keep evolving to keep up with its competitors and enemies who are also evolving. Thus, the Red Queen Effect: do nothing and fall behind, or run hard to stay where you are.

between universities and firms per se, but about a set of institutions and relationships among them embedded in a broader framework – the NSI. The NSI has a deep (and causal) relationship with development; therefore, the formation of an NSI was recognized as a precondition for overcoming underdevelopment.

Second, these perceptions came from different academic routes – development economics; studies of industrial sectors; investigations of characteristics of NSIs in the periphery; geography of innovation; investigations of the catch-up process; economics of innovation; and investigations of universities and their functions in different societies. Therefore, our tri-continent research teams were not a homogeneous group.

Third, we shared a common discomfort with the lack of studies about interactions between firms, universities, and research institutes in the South, to use a term from the IDRC competition.

Fourth, we were influenced by the strong academic and intellectual incentives created by the Catch Up Project led by Richard Nelson.

Fifth, there was a common feeling that this subject could be investigated in our countries by adapting and improving existing surveys (e.g., the Yale Survey and the Carnegie Mellon Survey), and by inventing new questionnaires that would fit our realities while retaining some comparability with the United States and other developed countries.<sup>4</sup>

Finally, we shared an implicit theoretical background, which was united by a common understanding of the concept of NSI, and mixed with the specific and diverse research subjects previously faced by each research team in our day-to-day academic activities in different national and regional realities.

The starting point of this research was not a solid and consolidated theoretical background. There was a diversity of views on interactions. The theoretical backgrounds for each of our research reports were prepared with a broad review of existing literature on interactions. This diversity of views, instead of being a weak point, was in fact a strong asset to our research effort. This diversity allowed the research to capture the mosaic of channels, modes, and forms of interaction prevailing in our 12 countries. This diversity also helped advance a theoretical view that incorporated the specificities of our 12 countries in a more general theoretical framework – an important challenge for this book.

Beyond this theoretical challenge, there is an important finding that first appeared as a new problem and in the end opened a new avenue for

<sup>4</sup> In 2004–2005, a pilot project was conducted in Minas Gerais, Brazil – an adaptation of pioneering surveys on an immature NSI (Albuquerque et al. 2005; Rapini et al. 2009; Chaves et al. 2012).

our research: interactions between firms, universities, and research institutes must be investigated within a global context. Our empirical work in all countries always led us to international links that must be taken into account. The persistent reference to international links in our field work should not be a surprise. Classic studies of the economics of science and technology have suggested how science and technology has a tendency to overcome national boundaries. Nelson and Rosenberg (1993, p.17) discuss this trend under “national systems and transnational technology,” and stress that there is a tension between attempts to “implement national technology policies . . . in a world where business and technology are increasingly transnational” (p. 18). In our research, with our focus on the interactions themselves, the push toward international flows was uncovered many times.

In each country we did find fingerprints – more visible or less visible hints – of international flows that connect firms, universities, and research institutes among different countries: firms in one country that are connected with universities and research institutes abroad; foreign firms that have contact with research groups working within local universities or research institutes; and subsidiaries of transnational corporations with connections to universities or research institutes both in their home and host countries.

During our field work we collected enough evidence to trigger an impression that with our national focus – inevitable given the design of our research – we were capturing only part of a broader picture. Our research was lucky enough to collaborate during 2009 and 2011 with a project on Global Innovation Networks, led by Jo Lorentzen. This project, INGINEUS, allowed three research groups<sup>5</sup> to work on the relationship between local and global interactions among firms, universities, and research institutes. This effort resulted in a tentative theoretical framework to deal with these cross-border flows. Our empirical work made us face a new theoretical challenge that pushed us to enrich our theoretical framework (see Chapter 8).

There were some differences between the approaches taken on each continent. Africa needed a theoretical framework able to deal with countries at different stages of development, including least developed countries. A specific concern about how to deal with innovation in the poorest countries is put forward by Lorentzen and Mohamed (2010): the lens

<sup>5</sup> Centre for Development Studies (CDS), India; Human Sciences Research Council (HSRC), South Africa; and Centro de Desenvolvimento e Planejamento Regional, Universidade Federal de Minas Gerais (Cedeplar-UFMG), Brazil, collaborated through the project Impact of Networks, Globalisation, and their Interaction with EU Strategies, 2009–2011 (INGINEUS).

necessary to grasp innovative efforts in these countries is not available in the existing literature on interactions – an understanding of innovation in these countries “requires an analytical apparatus we do not have” (p. 7). These reflections have an important implication for our research because “in many LICs [low-income countries] . . . firms are a relatively less representative actor” (p. 15). Rural livelihoods, agriculture, and health are subjects that have more importance, stresses Lorentzen. Starting from this point, Kruss et al. (2012) attempted to integrate the three levels of development of Uganda, Nigeria, and South Africa by using the “transition of phases” approach proposed by Sercovich and Teubal (2008) – a three-phase trajectory that fitted the positions of the three countries. The integration between Lorentzen and Mohamed (2010) and Sercovich and Teubal (2008) is fertile because it shows the differences among the interactions at each level of development, the differences between the actors and their size, and the implications for the elaboration of public policies for the transition between each phase. The results collected by the three studies in these countries capture empirically those differences (see Chapter 1).

The main question in Asia was how to deal with dynamic transformation – especially the recent catch-up process in South Korea and the fast changes taking place in China. These dynamic transformations demanded a theoretical framework within which the changes could be captured. In South Korea, for example, there were very specific dynamics between different institutional actors during the last three decades – public research institutes accounted for the key interactions with firms during the 1970s and 1980s, but investment in universities has grown since the 1990s (Eom and Lee 2009, pp. 501–504). Another example of institutional changes comes from China: the main modes of interaction during the 1980s – University-Run Enterprises (UREs) – are currently fading away in favour of horizontal university–industries links (see Chapters 2 and 4). These visible dynamic changes motivated Eun et al. (2006) to propose a framework based on the “absorptive capabilities” of firms and the stage of evolution of universities and their specific and changing roles – later defined by Liefner and Schiller (2008) as “academic capabilities.” As the capabilities of firms, universities, and public research institutes evolve, the nature, the channels, and the reasons for the importance of universities to firms change. The empirical evidence collected by the teams from China, India, South Korea, Malaysia, and Thailand provides an array of dominant patterns of interaction, which expresses not only the fast changes in the region, but the differences in terms of stages of development and the push toward technological upgrading (see Chapter 2). In comparison with Africa, Asia’s theoretical framework needed to deal both with differences in stages of development, size, and maturity of the NSIs, and with

the speed and scope of the changes taking place – China now, and South Korea earlier, show how the speed of these changes differentiates them from India, Thailand, and Malaysia.

Latin America is a more homogeneous continent. Mexico, Costa Rica, Argentina, and Brazil have a less dispersed level of development (they have all been in regime of interaction II since 1982), a more common set of problems, and a more homogeneous historical process – all are former colonies of Iberian countries (see Chapters 3 and 7). In contrast with Africa, the countries are more homogeneous and are at the same level as South Africa (Kruss et al. 2012, p. 519) – Mexico, Argentina, and Brazil share with South Africa similar problems related to the level of income inequality. In contrast with Asia, Latin America presents more uniformly stagnant growth. The stage of formation of the NSIs in Latin American countries is generally considered to be incomplete or “weak” (see Chapter 3). This diagnosis suggests that the formation of NSIs must go ahead and that interactions must change as underdevelopment is overcome. The theoretical framework elaborated by Arza (2010) is rich enough to provide an excellent snapshot of existing channels and flows of information in Latin America. This relative homogeneity may account for the feasibility of the continental econometric exercises summarized by Dutrénit and Arza (2010) and the matrices of interaction prepared for Mexico, Argentina, and Brazil (see Chapter 7).

The stage of the debates on the role of universities and their interactions throughout Latin America is captured by Arza’s theoretical framework, which accordingly investigates how different channels of interaction may or may not be beneficial to universities. The model integrates the data collected in two surveys, and evaluates the risks involved in “commercial” and “services” interactions as compared with “traditional” and “bi-directional” interactions. This evaluation makes sense because it draws on the current Latin American distrust of prevailing modes of interaction, and demands an examination of their risks and benefits. One motivation for Arza’s (2010) framework may be a suspicion that existing universities would be pushed to very early privatization of knowledge. This study, combined with other approaches, may be an important building block for a dynamic framework that takes into account the possibility of a transition from one dominant pattern of interaction to another pattern of interaction that is more sophisticated, more complex, and includes more feedback between universities and firms.

These three approaches show how different realities and trajectories demand a different lens for investigation. The richness of the empirical findings provided by these approaches – and sometimes their controversial interpretations – is shown in the chapters of this book. The empirical

findings are rich enough to question conventional wisdom and perceived truths. This new knowledge contributes to our effort to integrate those approaches into a more global view of the interactions between what Nelson and Rosenberg (1993) called “major institutional actors” of the NSI approach. Hopefully, our efforts will do more than fill gaps in studies on interactions between firms and universities in emerging and less developed countries. There are dimensions of those interactions that cannot be seen in the United States, Europe, or Japan. There are aspects and features of these interactions that could not have been seen if we had investigated Uganda, China, or Mexico alone. By combining our research in 12 countries in three continents, we have created something else – a more universal and dynamic view of the interaction between firms and universities in developing countries.

## THEORETICAL BACKGROUND: STARTING POINTS

The theoretical background prepared by the three continental teams surveyed the literature on interactions. Lorentzen and Mohamed (2010) focused on the least developed countries in innovation studies and how they are discussed. Arza (2010) built her theoretical review on the pioneering works of Ernesto Sabato and authors within or influenced by the Triple Helix approach (Etzkowitz et al. 2000). Eun et al. (2006) built their proposal on transaction-cost economics and authors like Williamson (1985).

In common in all these works were Klevorick et al. (1995) and Cohen et al. (2002). Now, we are able to integrate their findings into a more dynamic framework: the snapshot captured by these pioneering papers may be interpreted as a sort of “provisional end result” of a long historical development – with the United States as the representative country for the regime of interaction III.

“Provisional” is used because technological development has not ended – for example, in adapting the questionnaire of the pioneering Yale and Carnegie Mellon (CM) 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 considered an empirical representation of what the large literature on interactions between science and technology put forward between the 1970s and the 1990s. Cohen et al. (2002) helped organize our research work by pointing to three key issues for our previous investigations and for the international RoKS research project: (1) how are different fields of science and engi-

neering important for different industrial sectors; (2) what are the most important sources of information for innovation by firms; and (3) through what channels of knowledge flows do firms and universities communicate?

However, the theoretical background that supported investigations of interactions between universities and firms within the NSI in the United States is inadequate for the non-developed world. The most important reason for this limitation is that in the NSI in the United States (and in other mature NSIs) there are strong “major institutional actors” working: both large top-level universities (Rosenberg 2000), and 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). These actors are the result of a long-term historical process, as both Rosenberg and Chandler point out in their books.

To deal both with underdevelopment (Furtado 1986, 1987) and with catching-up countries like South Korea, a dynamic framework is necessary. Because universities, firms, and the interaction between them are part of the conceptual framework of an NSI, this dynamic framework must deal with the specifics of NSIs at the periphery. These specifics include both the existence, nature, size, and quality of universities, and the existence, nature, size, capability, diversification, and variety of firms. 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 intensity of the links between 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.

## A QUESTION ABOUT METHODOLOGY

Our international research project prepared common research instruments – two questionnaires, one for firms and another for research groups, whether located in universities or in research institutes. Preparation of the questionnaires involved formal discussions between all teams. The meetings included the Milano Catch Up Meeting (September 2006), the IDRC Ho Chi Minh City Meeting (January 2007), and the First Latin American Workshop (September 2007). In addition, hundreds of emails were exchanged among the country teams, and valuable input was received from a patient and always helpful Dick Nelson. Informal conversations in Catch Up Meetings (since New York, May 2005) and in Globelics Conferences (since South Africa, November 2005), and specific academic

visits among researchers in this project, also helped shape these questionnaires. The format of the questionnaires is truly a product of international cooperation. It was a long learning process – we began to learn new things about interactions in our countries long before our field work.

It is important to understand how we developed our questionnaires. The questionnaire for innovative firms was based on the original questionnaires from the Yale Survey (Klevorick et al. 1995) and the Carnegie Mellon Survey (Cohen et al. 2002). They were adapted to our countries to reflect the present stage of development of our immature NSIs, which are distributed through regimes of interaction I and II (Figure I.1).

Questionnaire design was an important issue in our research. We followed four general principles: (1) adapt the questionnaire to handle the specific scientific and technological characteristics of immature NSIs; (2) focus the questionnaire<sup>6</sup> on the role of universities and public research institutes for industrial innovation; (3) maintain the flexibility necessary to include national differences in economic sectors (following International Standard Industrial Classification [ISIC] sectors) and academic disciplines (according to the Organisation for Economic Co-operation and Development [OECD] classification); and (4) keep as much comparability as possible with the original Yale and CM surveys.

Adaptation of the original questionnaires meant that: (1) our questionnaires were shorter and more focused; (2) the academic disciplines included in the questionnaires were different, because the science and engineering fields not mentioned in the CM survey are important for our 12 countries (veterinary, mining engineering, and agro-sciences); (3) new channels of interaction were included (technology parks and incubators, and the internet); and (4) universities and research institutes were investigated in two different questions (instead of being put together in one single question).

The second questionnaire was for research groups in both universities and public research institutes. The goal was to investigate the other side of the interactive relationship and to understand the impact of these inter-relationships on group production (e.g., papers and dissertations) and the origins of the initiative that led to the relationship.

The samples were defined in a flexible way, according to relevant sectors and universities in the country. However, during our research, we used other research tools beyond our questionnaires: interpretations of available data (patents and papers); surveys (firms and universities); case studies of selected points of interaction; and historical studies. This combination of different research tools was very helpful. No one research instrument

<sup>6</sup> Our survey corresponded to Section III of the Yale survey “The relationship of science to technology” and to Section III of the CM survey “Sources of information.”

can capture everything because each instrument has its “blind spot.” However, in combination, the instruments complemented each other.

The surveys were very informative, but they may provide only a partial image of the complete picture. For Latin American countries, for example, they help prepare matrices of industrial sectors and science and engineering (S&E) fields that show “spots of interaction” – not well distributed “points of interaction.” However, when historical studies focus on these points of interaction, they unveil the history behind each one of those points and the long-lasting nature of those interactions (see Chapter 7). 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, and highlights the importance of those points and how they matter for the economy. Historical studies show how important topics such as the process of state and nation building and social inequality are to understanding 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, and by the openness of firms and universities to our investigation. The conversations and negotiations between the different national teams about our research tools were also informative and truly enlightening.

## A MORE GENERAL THEORETICAL FRAMEWORK

Since early 2007, research has taken place in 12 countries and there are now at least 15 research reports, 40 articles presented in international and national congresses and conferences, 28 papers in peer-reviewed journals, two special issues in specialized journals, and three books. The integration of the theoretical background provided by the NSI literature, the contributions from the 12 research teams, and the synthesis provided by the chapters in this book provide safe ground for a new step forward: an elaboration of a more general and universal approach to interactions between firms and universities. The notes in this section dialogue with the theoretical models from the study of university–firm interactions in developed nations and extend those models to the study of catching-up processes in developing countries.

Our research findings have stimulated us to rephrase our previous hypothesis about the small significance of universities for less developed countries. During this research we learned how to find and evaluate

interactions between universities, public research institutes (PRIs), and firms and society. The result is an improvement in our understanding of the relevance of universities in all stages of development and our ability to identify the lack of universities, and their limits in terms of size and quality, as constraining factors for development.

Six aspects are examined: (1) the role of universities as antennae of technological changes; (2) the importance of universities and PRIs since the early stages of development; (3) the ways firms and society at large act as sources of multiple demands on universities and PRIs; (4) the dynamics of interactions, and matches and mismatches as a structural phenomenon; (5) the historical roots of interactions and structural changes; and (6) the inclusion of cross-border interactions.

### **Connecting the Periphery to Technological Revolutions at the Centre: Universities as Antennae**

The first building block is the role of universities as “antennae” of science and technology produced at the centre of the capitalist system. The nature of technological progress in capitalism was discussed by Marx (1867), who showed how the permanent revolution of technological basis is a key factor of capitalism. Later, Schumpeter (1939), Mandel (1974), and Freeman (1982) showed how technological revolutions, through long waves of capitalism development, shape and reshape the structures of the capitalist economy. The literature on interactions between science and technology in developed countries could be read as explaining how these technological revolutions are generated at the centre. Those technological revolutions repeatedly generated at the centre of capitalism are diffused throughout the whole world and impact the countries at the periphery of the capitalist system (Furtado 1986).

The impacts on the periphery of the waves of capitalist development change and reshape the challenges and opportunities for catching up.<sup>7</sup> This dynamic international technological framework is the context in which the universities at the periphery establish their first role. They are important channels to absorb knowledge generated abroad – to absorb knowledge from the centre of technological dynamics. The ability of countries at the periphery to access knowledge and technology from the centre is one important factor that changes the divide between the centre and the periphery: South Korea overcame underdevelopment, new capabilities acquired by firms and universities at the periphery changed their roles

<sup>7</sup> For a discussion of technological revolutions at the centre and their impacts on a peripheral country like Brazil over time, see Albuquerque (2007, Section 2.2).

in the international arena. There is a specific dynamic that reshapes the centre–periphery divide, including what Marques (2014) calls a “boomerang effect” – improvements at the periphery have feedback effects on the centre. In sum, the technological revolutions at the centre and technological learning at the periphery create a dynamic transformation of the nature of centre–periphery relations.

Chapter 8 shows that, among the global links that connect firms and universities, links between domestic and foreign universities are important for the transformation of domestic “university capabilities” or “academic capabilities” (Eun et al. 2006; Liefner and Schiller 2008). PhD students sent abroad, research cooperation, and scholar visits are important channels for improving capabilities within domestic research institutes and universities. Following this line of thought, previous contact between a foreign university and a domestic research institute is a precondition for a domestic flow between a local university and a firm (or a farm or a local need in agriculture or health). Later, this initial role is reshaped and updated. Domestic universities must have international contacts and links – that over time become more and more institutionalized – to reach new knowledge that later they may diffuse to local firms, local institutions, and eventually to local subsidiaries of transnational corporations (TNCs).

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” (Ribeiro et al. 2006, p. 90), just to preserve the existing technological gap vis-à-vis developed countries.

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

### **Universities and PRIs: Important since the Early Stages of Development**

Universities and PRIs are one of the first channels to connect a country at the periphery to international flows of science and technology.<sup>8</sup> The first universities and PRIs in less developed countries are created with foreign teachers and native students who 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

<sup>8</sup> Other forms of early connections to developed countries are travellers, traders, and study abroad.

the transnational flow of people in science and technology” (personal communication, 3 August 2009).

The decision to create local universities and local PRIs depends on the level of nation and state building. The date of creation of the first (relevant) universities and PRIs therefore is important information. Latin American countries have in common a late onset of their universities and PRIs (19th century), which is highly correlated with national independence and initial organization of national and public finances.

Late development, by definition, means high levels of poverty, inequality and 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. They must keep in touch with scientific and technological development at the centre while facing various new problems and issues (diseases, soils, plant varieties, and geologic and climatic conditions) that need specific investigations and might generate new scientific knowledge.

Furthermore, various tasks must be performed by universities and PRIs: teaching; training of human resources for public administration (especially at the beginning of nation-building processes) and for the creation of firms (e.g., state-owned infrastructure, and key mining and manufacturing sectors); diverse problem-solving tasks; and eventually (in the beginning) truly original scientific research (especially in agriculture and health).

Later, during the initial industrialization process, there seems to be a wave of institutional formation, with new PRIs and universities (at least faculties) created that may help to solve new (and more complex) problems. In the Latin American and African cases, we identify a combination of late industrialization and late beginning of local scientific institutions. However, both events are related to deep structural changes in society, which are a consequence of important political changes. Therefore, there is no automatic mechanism operating to push the process of institution 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, there may be requests from mining sectors to upgrade mining techniques, and there may be demands from governments to provide tests for infrastructure building. But there may also be institutional building ahead of the

demand (after some state initiatives) that should foster the creation of new industrial sectors.

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

In this new dynamic, the enlargement of universities and PRIs and consequent diversification (so important, according to Figure I.1) is a difficult process with social resistance. The size, diversity, and quality of universities depend on various social variables like the reduction of illiteracy and universal access to basic and secondary schools. These variables in turn depend on 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 the matrices prepared for Latin American countries (see Chapter 7).

As universities and PRIs grow, their dual role becomes more complex. They must perform their role as “antennae” for the local society and economy in a broader range of S&E fields, as these fields grow in number and scientific complexity at the centre. As well, local demands and local research questions grow in size and complexity. This role as “antennae” changes over time, with new tasks put forward by technological revolutions at the centre. But this role exists throughout all development phases: compare the role of National Agricultural Research Systems (NARS) in the diffusion of Green Revolution Modern Varieties (GRMVs) (Evenson and Gollin 2003) with 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 the first meeting of the Catch Up Project (Columbia University, May 2005), Robert Evenson put forward a clear relationship between universities (or at least higher education institutions) and the diffusion of GRMVs. Countries without the beginnings of a university system, or more specifically, countries with “failed National Agricultural Research Systems,” achieved no or very limited diffusion of GRMVs (with consequences for the pace of their industrialization process) (Evenson 2005, p.1 and p.3). Evenson and Gollin (2003, p.758) argue that NARS and International Agricultural Research Centres (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 GRMVs this knowledge is public. Furthermore, Evenson associates those “failed NARS” with “failed states” (Evenson 2005, p.1).

South Korea, now in regime of interaction III, is a good illustration of the catch-up process. Kim (1997) indicates how the South Korean government took the initiative in 1966 to create PRIs (Kim 1997, p. 84), ahead of any demand from existing firms. This type of state initiative was repeated in industries such as electronics (p. 207), and computers and semiconductors (p. 214 and p. 228) – in this case the PRI created was KIET. 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 labour and capital.

The evolution of local universities means that their roles become more diverse (e.g., teaching in new areas, research in various directions, following diverse motivations, and demands for advice for public policy and public health). This point summarizes what Eun et al. (2006) call “capabilities of universities,” later defined by Liefner and Schiller (2008) as “academic capabilities” – they are not static and show an evolutionary trend over time.

Finally, there is a specific dynamic between universities and PRIs. It is not possible to talk about universities and PRIs as if they are the same. One important difference between our questionnaires and the Yale and Carnegie Mellon questionnaires is the unfolding of one question on universities into two questions – one for universities and another for public research institutes. This new question came after an initial conversation during the first Catch Up Meeting (New York, May 2005), when Keun Lee made this suggestion, given the importance of public research institutes for the South Korean process. The combination of the interpretation of our questionnaires (see Chapters 1–6) with the historical evidence discussed for different countries, suggests a division of labour between these two institutions, both throughout countries and within each country over time. In the South Korean case, it is clear that the creation of PRIs was a short cut to overcome structural debilities with their universities. The speed of the process, and the specific roles of these PRIs in relation to firms, could not be performed by existing universities. Therefore, during the initial phases of South Korean catch up, interactions between firms and PRIs (with the leading roles by the PRIs) were important (Eom and Lee 2009, 2010). Later, as universities developed, they assumed new functions in their interactions with firms, leaving PRIs with other functions.

PRIs may begin the formation of domestic S&T institutions, and later change their roles as universities develop. They may also be instruments to articulate industrial policies with S&T policies. Eventually, PRIs may be transformed into universities.

## **Firms, Farmers, and Society: Multiple Sources of Different Demands on Universities and PRIs**

Even in least-developed stages, there are demands on universities and PRIs to transfer publicly available knowledge from 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 NARS. Similarly, 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. In Uganda, according to Kruss et al. (2012, p. 525), “interactive activity was concentrated at a large, long established university based in the capital city, where emergent networks were evident. For the most part, these network projects were oriented to break poverty traps and to deal with problems of human development and the challenges of knowledge intensification of traditional agricultural activities to enhance productivity.” Lorentzen and Mohamed (2010, p. 13) stress the dominance of those demands in comparison to issues related to industrial firms in the least developed countries.

This remark is important because during our investigation we dealt repeatedly with a focus only on university–industry links. Indeed, more developed countries (and more developed regions within a large and uneven country) also have these demands on health and agriculture presented to universities and PRIs that go beyond the strictly industrial dimension. One important feature of underdevelopment is heterogeneity – countries like India, Mexico, South Africa, and Brazil have within their borders regional inequalities that make their epidemiologic profile very specific, a combination of health problems typical of the poorest countries of the world (communicable diseases such as malaria and schistosomiasis) and health problems typical of richer countries (chronic diseases such as Parkinson’s and Alzheimer’s). Therefore, universities and PRIs should preserve this sort of broader relationship and interaction with society throughout all phases of development.

Firms depend on universities for trained human resources (e.g., engineers, chemists, biologists, and software professionals). Today it seems 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. This relationship may be overlooked by the traditional field of industrial economics.

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

Eun et al. (2006) emphasize the absorptive capabilities of firms and the specific dynamic that their growth determines. The growth of the capability of firms is correlated with the growth of the importance of universities to firms. Dynamically, this means that, as the capabilities of firms increase, new demands on universities and PRIs emerge.

New firms are created all the time. What kinds of firms are created and how long they will survive depends on several factors. Studies on the birth, survival, mortality, and growth of firms are important. The creation of new firms also highly depends on other social and political conditions such as: access to credit (public and private); educational conditions (the educational level of founders of the firm matter, because in certain industrial sectors university training may be necessary to create a firm); and the absence of social, colonial, or ethnic constraints (in Brazil, the Portuguese prohibited manufacturing activities until 1808, and 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, like the process of university formation, also depends on broader social conditions. Gerschenkron (1952) showed that, for latecomers, industrialization is not an automatic process; on the contrary, it is a process highly dependent on institutional innovations such as banks (industrial and development) and state initiatives for firm creation in key sectors.

The vitality, sectoral nature, and spread of this process of creating new firms 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, TNCs impact the whole process because they are a historical product of capitalist development at the centre 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.

In an opposite direction, local firms may grow in size and capabilities and place new demands on local universities that cannot be answered by them. Thus, these local firms may establish direct contacts with foreign universities, both for complex problem solving and for technological upgrading – this is the case in China (see Chapter 4, Tables 4.8 and 4.9).

### **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 the capabilities of both universities and firms. As Figure I.1 shows, the sizes of universities and PRIs matter because thresholds of critical mass must be overcome. Figure I.1 may also have a qualitative interpretation: the quantitative steps taken by South Korea between 1974 and 2006, jumping from regime of interaction I to regime of interaction III, are related to qualitative changes related to entering new industries, especially information and communication technologies (see Kim 1997). These basic factors underlie the multifarious interactions between universities and firms.

The workings of the channels of knowledge flow investigated by Cohen et al. (2002) have a historical evolution. First, there is a process of change in university capabilities. Initially, universities and PRIs may provide human resources, testing, and simple problem solving (e.g., consultancy and 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 complement research and development (R&D) by firms. Second, there is a process of change in the capabilities of firms. 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 may become part of the agenda.

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

An important finding of our research is the relevance of universities and PRIs even to low-technology sectors. For countries in Regime II (e.g., South Africa and Latin America), one research finding is that existing “points of interaction” have long-lasting historical roots: the mining sector and PRIs in South Africa (Pogue 2006; Kruss 2009b); agricultural products, iron, and steel in Brazil; iron and steel in Mexico; and agro-sciences and food industries in Argentina (see Chapter 7). These historical roots are illustrated by the mining sector: in South Africa (Pogue 2006) and Brazil (Carvalho 2002), faculties and universities were important to bring updated knowledge from developed

countries to existing local firms in South Africa, and to create new firms in Brazil.

There is a learning process, both by the firms and the universities, after the interactions begin. These relationships have a proper logic, and are a sort of spontaneous process. This internal dynamics of each point of interaction may involve shared knowledge, mutual trust, transfer of personnel between the two actors, and a better understanding of each other – a sort of logic that Williamson (1985) evaluated using a transaction-costs framework. The history of these interactions may be short lived or last longer. 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 (unveiled by case studies of points of interactions).

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 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 also matter because universities have access to state and to township and village resources that may be used to fund new firms that they create. This Chinese specificity, as Eun (2005) explains, has historical roots that can be traced to 1949, the foundation of the People's Republic of China. Eun mentions three peaks of AREs – during the Great Leap Forward, during the Cultural Revolution, and after Deng's reforms (especially the S&T reforms).

These remarks suggest that matching of universities and firms is an exception. The norm, especially during a catching-up process, is a mismatch between universities, PRIs, firms, and farms.

Because universities and PRIs have access to available international knowledge that is not available locally, they provide technological opportunities to existing and new firms. This form of technological opportunity is a specific feature of technological progress at the periphery. Compare this form of technological opportunity with those discussed by Dosi (1988b). These technological opportunities provided by local universities and PRIs may or may not be wasted, depending on the dynamics of firm creation and the capabilities of the firms. Over time, even when universities and PRIs are doing their job properly, mismatches with industries may take place.

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

As in the centre, in the periphery there are structural differences in the roles of universities, PRIs, and firms, which are a consequence of a division of labour within the NSI. These differences are translated into problems of timing, goals, and points of view. These problems are perceived by the actors as mismatches – and are well captured by our surveys.

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 contact with foreign universities. These contacts may have spillover effects on both local firms and local universities.

Subsidiaries of TNCs may need to strengthen the local academic capabilities of existing universities or local public research institutes to answer specific needs. Eventually, they may send employees to their headquarters for training in their R&D laboratories. This training may be useful both for their subsidiaries and for local universities – this employee may become a teacher or a researcher.

As in developed countries, there are, from time to time, conflicts regarding the role of universities and public research institutes around issues such as the nature of the research to be undertaken (basic, applied, a combination of both) and their relationships with firms and the private sector. These conflicts may be seen as part of the efforts to adapt institutions to new tasks and the new challenges put forward by the development process.<sup>9</sup>

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

### **Structural Changes and Interactions in Historical Perspective**

Social and political factors matter for the formation and growth of universities, PRIs, and firms – the whole process is neither a smooth process nor only quantitative growth. On the contrary, the processes depend on structural changes that overcome constraints and open new avenues for institutional formation and innovation. Examples of landmarks in these processes are national independence, abolition of slavery and ethnic

<sup>9</sup> Richard Nelson, personal communication.

segregation, industrialization, democratization, and reformist movements for universal education. Waves of institutional formation seem to be correlated with these landmark events.

Development is a complex and multi-causal process; therefore, the stress on the role of NSI for development does not in any way suggest a mono-causal approach. On the contrary, this research, while focusing on the specific building blocks of an NSI, informs a deeper understanding about how the process of university formation depends on 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 and in Africa seems to be correlated with Latin American and African late industrialization (see Chapters 1 and 3).

Our discussions and literature reviews help to differentiate at least three patterns in the formation of universities and PRIs: (1) failed states lead to failed universities and PRIs (Evenson and Gollin 2003); (2) states captured by elites (e.g., Brazil and South Africa under apartheid) or states that only “discipline labour” lead to limited “islands of excellence” (Amsden 2001; Terreblanche 2002); and (3) states with capabilities to indicate strategic areas for private investment lead to the dynamic creation of PRIs, guide the interaction of PRIs with firms by way of industrial policies, and overcome underdevelopment (Amsden 1989).

This differentiation, very introductory but illustrative of more general trends (deeper socio-historical currents), highlights the complexity of studying universities and their interactions. Indeed, there may be a great challenge for all countries in our research: how can democratic and participatory processes improve decision making about complex subjects such as the allocation of resources for science and technology? This would add a new building block to the framework of NSI: the relationship between democratic processes, public policies, and the maturing of NSIs.

The non-linearity of those processes, given the peripheral condition of the countries involved (with the exception of post-1990s South Korea) is also affected by the uncertain pace of technological revolutions at the centre. Given these technological revolutions, the whole university system must be re-adapted again and again, otherwise the technological gap in comparison to developed countries may widen. Technological revolutions at the centre determine another structural feature of the interactions at the periphery: the tasks of the educational system increase because old and persistent unsolved issues (e.g., illiteracy and communicable diseases) now must be tackled together with new issues (e.g., access to computers and internet, and teaching activities in new S&E fields, like nanotechnology and biotechnology). The nature of the whole process is related to structural changes: advances from one phase to another are related and caused by structural changes.

## **The Global Context in which the Interactions Take Place**

The tension pinpointed by Nelson and Rosenberg (1993, p.17) between “national systems of innovation and transnational technologies” was intensely felt during the implementation of our research. Certainly since 1995 the process of internationalization of capital has been deeply intensified. This intensification, sharper in the S&T realm, was combined with our approach to this subject: in many ways, our research teams had to deal with international flows connecting our “major institutional actors” across borders. The end result is a clear perception that we cannot deal with interactions without adding an important global context. The international flows and the international connections also have a dynamic dimension: they change the nature, types of flows, modes of interactions, and even the direction of the flows over time.

The presence of these international flows is so pervasive that it is no longer sufficient to mention TNCs and their impact – they need deeper investigation. The last chapter of this book suggests a tentative taxonomy to make sense of these international links. The TNCs investigated by our research teams have links with universities in their home countries: the firms investigated by Klevorick et al. (1995) and Cohen et al. (2002) contain TNCs whose headquarters are in the United States. Narin et al. (1997) had already shown how a global firm like IBM is able to use knowledge produced by US and foreign universities – our research captured part of this picture, the part where an IBM subsidiary had contact with a local university.

The diversity of possible links is large: Adeoti et al. (2010, p.102) describe how Nestlé in Nigeria works with the Federal University of Agriculture, Abeokuta (UNAAB), and has contributed to its improvement. Fiat has a network of R&D departments distributed worldwide and an engineer working in a Brazilian R&D department may be sent to an Italian university with deep and long-lasting links with their headquarters for additional training. This engineer may return to Brazil and become a teacher in a local university.

TNC subsidiaries in peripheral countries may not have any links with local universities, but they have “indirect” links with foreign universities. Eventually, TNCs may establish links directly with local universities without local subsidiaries. TNCs must be taken into account when considering diverse and new channels of knowledge flow, and determining the specifics of new interactions at the periphery. For our research, it is important to understand how and why TNCs may define a hierarchical “internal division of labour” that combines contacts with local and foreign universities.

The tension between “national systems of innovation” and “transnational technology,” as indicated by Nelson and Rosenberg (1993), has increased so much that now it is necessary to rephrase questions about local interactions between firms, farms, and universities across the world – these interactions might be seen within a context shaped by the beginnings of a global innovation system.

## ORGANIZATION OF THIS BOOK

This book results from our tri-continent research effort. Its preparation began in Cape Town, South Africa, in August 2009, the concluding meeting of our RoKS project, and proceeded with an International Workshop that took place in São Paulo, Brazil, in September 2011, focused on the organization of this book. A first round of results was published: Africa published in the *Journal of Development Studies* (Kruss et al. 2012), Asia in a special issue of the *Seoul Journal of Economics* (Eom and Lee 2009), and Latin America in a special issue of *Science and Public Policy* (Dutrénit 2010). These first syntheses, grounded on country-based papers, fed our reflections and the organization of this book by continental and thematic chapters – facing new challenges put forward by our findings and our reflections about those findings.

The chapters of this book indicate the dominant patterns of different types of interaction, showing which pattern prevailed in each country and suggesting how these dominant patterns may change over time – as this introduction suggests.

This book is organized in three parts. The first part – “Interactions across regions at different stages of development” – has four chapters.

Kruss, Adeoti, and Nabudere, in the first chapter on Africa, focus on three countries at appreciably different levels of development: Uganda, Nigeria, and South Africa. The study examines the constraints and the features of identifiable cases of university–firm interactions, with the broad objective of ascertaining how to address the constraints and promote a more productive regime of university–firm interactions, appropriate to these African contexts.

Schiller and Lee, in the second chapter on Asia, present the cases of Korea, Malaysia, Thailand, China, and India. These five countries cover most of the differences that exist among emerging Asian economies in terms of duration of the catch-up process (early and late starters), size (large and small countries), and developmental policies (active and passive approaches).

Dutrénit and Arza, in the third chapter on Latin America, investigate

Mexico, Costa Rica, Argentina, and Brazil, discuss the results, and extract a set of features on the interactions between universities, public research institutes, and firms, particularly relevant to the relationship between channels and benefits.

Eun, Wang, and Wu, in the fourth chapter, show that a transition is going on in the mode of knowledge transfer from university to industry in China.

The second part – “Dynamic interactions: matches and mismatches over time” – has three chapters.

Pinho and Fernandes, in the fifth chapter, using data from our 12 countries, address the modes of relationship, the ranking of universities and PRIs among the sources of information, and the degree of success of this relationship.

Arza, De Fuentes, Dutrénit, and Vazquez, in the sixth chapter, conduct a comparative analysis of channels of interaction and derived benefits from interaction across our 12 countries.

Albuquerque, Suzigan, Arza, and Dutrénit, in the seventh chapter, present matrices of the interaction of the economic and industrial sectors with the science and engineering fields for Argentina, Mexico, and Brazil.

The third part – “Toward a framework of global interactions between universities and firms” – has one chapter. Ribeiro, Britto, Kruss, and Albuquerque, in the eighth chapter, suggest a typology to deal with global interactions and investigate empirically the international flows between firms and universities.

Finally, in a Postscript, O’Brien and Bortagaray analyse the experiences of our research programme and seek to conceptualize and quantify university–industry links in countries in Asia, Latin America, and Africa.

