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Executive Summary

This WP focuses on a very specific subject of the innovation literature: how institutions matter for the formation of Global Innovation Networks. WP7 has three different research papers, two focusing on the institutional framework involving universities and firms - key building blocks of national systems of innovation – and one discussing intellectual property rights.

The **first research paper** ("The role of institutional frameworks and local-global interactions in the emerging countries in the emergence and evolution of GINs") investigates the specific role of this key component of Innovation Systems to the formation, spread and improvement of Global Innovation Networks.

This specific focus on GINs and interactions between firms and universities is articulated with another particularity of this WP: a look from the so-called South. South Africa and Brazil are part of the periphery of global capitalism, as scholars as Raul Prebisch and Celso Furtado put forward. Within this broad periphery, South Africa and Brazil (together with India, the subject of the second research paper) have a very peculiar position, sharing challenges and opportunities.

The starting point of this first research paper is a theoretical evaluation of GINs and interactions between firms and universities, which suggests a tentative "taxonomy" of different types of global interactions. It is an attempt to grasp the diversity of channels and directions of those increasingly complex relationships between firms and universities. This taxonomy is used also in the second research paper (A7.2).

Once this taxonomy is presented, the next step is to introduce selected science and technology indicators both to identify how interactions between firms and universities differ across the world and to locate the very specific position of South Africa and Brazil in this regard. Then there is the analysis of a Survey prepared by the INGINEUS Project, focusing in the questions related to the nature of technology activities of interviewed firms and how they collaborate with universities and research institutes. This analysis clearly differentiates countries and NSIs regarding the nature and quality of their role in global interactions between firms and universities. The next section summarizes the Innovation Surveys of South Africa and Brazil, presenting data that help to differentiate the innovative activities of domestic and foreign firms, and how capital ownership matters for the shape and scope of interactions between firms and universities. Foreign firms rely strongly on internal networks as source of technology – and this is a clear difference vis-à-vis domestic firms, although they also have interactions with local universities. The following section – based on a Survey on Interaction between firms and universities in Brazil - provides data to deepen this analysis. The results, again, stress the importance of the NSI (general environment) to shape the nature and the intensity of interactions between domestic and foreign firms and local universities. A conjecture is that the foreign firms adapt themselves to the general conditions of a NSI – which would lead to a conclusion that improvements in a NSI would afect both domestic and foreing firms. Finally, the research paper summarizes the main findings of case studies implemented in South Africa (agro-food sector) and Brazil (auto industry) showing how local R&D departments and activities in local subsidiaries are integrated within the network of TNCs – and how hierarchical relationships are present, especially in the current stage of development.

The **second research paper** ("University Industry Interaction in Global Innovation Networks. The case of ICT GINs in India") focuses on India and ICTs. It also uses the primary data collected as part of INGINEUS survey, intending to contribute towards our understanding of the patterns and determinants university interaction by taking the case of ICT sector in India. The study finds

important variation in the occurrence in university industry interaction across firms belonging to different organizational categories and regions. The study highlights significant institutional and policy deficit and calls for addressing these deficits such that Global Innovation Networks do not turn out to be Global Innovation Traps.

The **third research paper** ("Intellectual Property Rights, Migration, and Diaspora") studies theoretically and empirically the role of the interaction between skilled migration and intellectual property rights (IPRs) protection in determining innovation in developing countries (South). This paper shows that although emigration from the South may directly result in the well-known concept of brain drain, it also causes a brain gain effect, the extent of which depends on the level of IPRs protection in the sending country. This comes from a diaspora channel through which the knowledge acquired by emigrants abroad can flow back to the South and enhance the skills of the remaining workers there. This paper argues that by increasing the size of the innovation sector and the skill-intensity of emigration, IPRs protection makes it more likely for diaspora gains to dominate, thus facilitating a potential net brain gain. The main theoretical insights of this paper are then tested empirically using a panel dataset of emerging and developing countries. The findings reveal a positive correlation between emigration and innovation in the presence of strong IPRs protection.

The review of the literature, our tentative taxonomy, and the field work of the Project INGINEUS have helped us to evaluate one central question: whether global innovation networks in emerging countries are a path for improvement within the international division of labor or a blocking factor for the development of national innovation systems globally integrated. Our answer is in line with a recent evaluation from Ernst (2009, p. 6 and p. 38): GINs may be a "mixed blessing", even a "poisoned chalice". On the one hand, the preservation of hierarchies is a barrier to more advanced, technology-rich, international interactions. On the other hand, existing GINs may, under certain conditions, trigger processes that may lead to technological upgrade of peripheral countries. However, as Ernst (2009, p. 38-48) emphasizes, public policies matter for a more positive development of GINs. In our theoretical framework, this is one feature of the NSIs determining the nature of GINs.

The role of institutional frameworks and local-global interactions in the emerging countries in the emergence and evolution of GINs

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Executive summary

The focus of this WP is one very specific subject of the innovation literature: interactions between firms and universities. The contribution of WP7 is the evaluation of the specific role of this key component of Innovation Systems to the formation, spread and improvement of Global Innovation Networks.

This specific focus on GINs and interactions between firms and universities is articulated with another particularity of this WP: a look from the so-called South. South Africa and Brazil are part of the periphery of global capitalism, as scholars as Raul Prebisch and Celso Furtado put forward. Within this broad periphery, South Africa and Brazil have a very peculiar position, sharing challenges and opportunities.

The starting point of this Report is a theoretical evaluation of GINs and interactions between firms and universities, which suggests a tentative "taxonomy" of different types of global interactions. It is an attempt to grasp the diversity of channels and directions of those increasingly complex relationships between firms and universities. This taxonomy seven types of interactions: 1) only local interactions; 2) international interactions of local firms; 3) transnationals interacting only with home country universities; 4) transnationals interacting both with home country and host country universities; 5) a type that may mix characteristics from the four types above; 6) a non-hierarchical network between TNCs headquarters and subsidiaries and their connections with universities; 7) international consortia between firms and universities.

The role of South African and Brazilian firms and universities in those types of interactions is a consequence of their position in the global science and technology scenario. South Africa and Brazil are located in the upper strata of the capitalist periphery, according to methodology that clusters the world in three different "regimes" of interaction between science and technology. South Africa and Brazil are in the "regime" II, a regime that faces the curse of the "Red Queen Effect": the upwards movements of those two countries are not enough to reduce the gap to the threshold limits the "regime" of developed countries. This position has a lot to do with, inter allia, the nature and sectoral position of domestic TNCs.

This specific position of South Africa and Brazil is well described by the data analysis of INGINEUS Survey. The statistical technique of Multiple Correspondence Analysis (MCA) shows a clear differentiation of countries and sectors, when the data related to interactions with universities are evaluated. For the agroprocessing sector – that includes South Africa – there are two profiles, very well defined, that clusters South Africa and Denmark in opposite quadrants. For the auto sector – that includes Brazil – there is also a clear delimitation, that shows Germany (headquarter of TNC,

internal R&D and intense interactions with universities) in one quadrant, Brazil (host country of TNCs, low R&D and low level of interactions with universities) in an opposite one, and Sweden in a different profile (stand alone firms). The analysis of the INGINEUS Survey data, therefore, stresses the dependence of innovation networks upon the nature of NSIs and the presence and spread of home-based TNCs.

The Innovation Surveys of South Africa and Brazil present data that help to differentiate the innovative activities of domestic and foreign firms, and how capital ownership matters for the shape and scope of interactions between firms and universities. Foreign firms rely strongly on internal networks as source of technology – and this is a clear difference vis-à-vis domestic firms, although they also have interactions with local universities. Since foreign firms are proportionally more innovative than domestic firms, they also tend to have links with local universities.

A Survey on Interaction between firms and universities in Brazil provided data to deepen this analysis. The descriptive analysis of the data showed that although there are some differences in patterns of cooperation of NCs and MNCs, the interactions of these firms and universities/PRIs are usually quite similar. The main difference found is related to the reasons for collaboration. Additionally, the use of the Multiple Correspondence Analysis method suggested that it is not possible to distinguish patterns of interaction between universities and firms based on the origin of their capital, for the variables analyzed in this study. These results, again, stress the importance of the NSI (general environment) to shape the nature and the intensity of interactions between domestic and foreign firms and local universities. A conjecture is that the foreign firms adapt themselves to the general conditions of a NSI – which would lead to a conclusion that improvements in a NSI would afect both domestic and foreing firms.

Case studies on subsidiaries of agroprocessing TNC in South Africa and auto TNC in Brazil show a clear division of labor between R&D departments in the home country and in the host country, with hierarchies well defined. This hierarchical relationship is not static, however: over time, there have been improvements with the network between TNC headquarters and subsidiaries and their connection with universities. Once a team in charge of local R&D activities has been formed, a new process is created, with its own new dynamics. These dynamic effects are also present in the relationship with universities, since there may be R&D researchers and engineers with formal connections to local universities (as teachers, for instance), who naturally establish ties between local universities and local R&D department. There will be informal ties, also, since engineers and researchers from the local subsidiary may take graduate courses in local universities and very likely use problems of the R&D department as the subject of their dissertations and theses. These informal interactions also may develop over time.

The review of the literature, our tentative taxonomy, and the field work of the Project INGINEUS have helped us to evaluate one central question: whether global innovation networks in emerging countries are a path for improvement within the international division of labor or a blocking factor for the development of national innovation systems globally integrated. Our answer is in line with a recent evaluation from Ernst (2009, p. 6 and p. 38): GINs may be a "mixed blessing", even a "poisoned chalice". On the one hand, the preservation of hierarchies is a barrier to more advanced, technology-rich, international interactions. On the other hand, existing GINs may, under certain conditions, trigger processes that may lead to technological upgrade of peripheral countries. However, as Ernst (2009, p. 38-48) emphasizes, public policies matter for a more positive development of GINs. In our theoretical framework, this is one feature of the NSIs determining the nature of GINs.

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Introduction

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This combination of specificities informs the structure of this Report.

The first chapter presents the theoretical framework to integrate global innovation networks and interactions between firms and universities. This theoretical framework generates a taxonomy of interactions between firms and universities at the global level – with seven types.

The second chapter summarizes previous works – that may have been the reason for the participation of our research group in the INGINEUS Project -, selecting science and technology indicators both to identify how interactions between firms and universities differ across the world and to locate the very specific position of South Africa and Brazil in this regard – a first approximation to understand the specificities of their roles within GINs.

The third chapter analyses the Survey prepared by the INGINEUS Project (WP2), focusing in the questions related to the nature of technology activities of interviewed firms and how they collaborate with universities and research institutes. This chapter, since it explores all sectors and countries, helps to locate the sectors investigated in our case studies in a more global framework.

The fourth chapter evaluates data gathered by the South African and Brazilian Innovation Surveys, investigating how capital ownership matters for interactions with universities.

The fifth chapter explores a database prepared by a previous research (RoKS Research on Interactions between firms and universities, 2007-2009), available only for Brazil, that provides information on the differences between local and foreign firms regarding sources of information and channels of information flows between them.

The sixth chapter summarizes the main findings of case studies implemented in South Africa and Brazil, to understand how local R&D departments and activities in local subsidiaries are integrated within the network of TNCs.

The conclusion summarizes the main findings of this report and indicates avenues for further research.

CHAPTER 1: GLOBAL INTERACTIONS BETWEEN FIRMS AND UNIVERSITIES

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1.1 INTRODUCTION

The INGINEUS Project offers a great opportunity to students of the interaction between firms and universities to broaden their horizon and understand their subject in a global context. Previous studies - whether in the North (Klevorick et al, 1995) or in the South (Lee, 2009; Kruss, 2009; Dutrénit, 2010) - have been able to capture only part of the total picture. Research on global innovation networks (GINs) provokes students of interaction to advance towards a real global perspective. Indeed, as international connections are more widespread and more active than is typically assumed or explicitly stated, this global view is a better starting point for a study of interaction, or even a necessary starting point, given the global nature of science and technology.

The starting point of this paper is thus a review of two different strands of the literature on innovation - first, the literature on interaction (Klevorick et al, 1995; Nelson, 1993), and second, the more recent literature on GINs (Ernst, 2006; *The Economist Intelligence Unit*, 2007). These strands share a common problem: each has a blind spot in relation to the core focus of the other strand. The literature on interaction does not consider the international dimension in any depth, and the GINs literature does not integrate the university dimension adequately.

The paper addresses the common weakness through a combination of the two approaches, searching for interactions between firms and universities globally. It includes the global dimension in the first approach and universities in the second. A critical review of the available literature in Sections 1.2 and 1.3 summarizes the strengths of each strand, and how they deal with each other's primary focus. On this basis, Section 1.4 introduces a tentative framework on global interaction between firms and universities.

1.2 GLOBAL INNOVATION NETWORKS: A REVIEW OF THE LITERATURE

The intellectual trajectory of Dieter Ernest's work has been seminal to investigate the international nature of production and innovation, with a special focus on the rising East Asia economies. Ernst proposed the concept of *global innovation networks* (GINs) after investigation of global production networks, knowledge flows and the changing geography of innovation systems (Ernst, 2002; Ernst & Kim, 2002). The empirical focus of this work was the changes brought about by one dynamic and deeply internationalized industrial sector, semiconductors (Ernst, 2005), a sector that is increasingly located in Asia. This offered an excellent site to follow the increasing flow of capital (through FDI) and knowledge (people, R&D investments, firms' acquisitions) between the US and Asia. Ernst (2006) reviewed the scholarly literature necessary to support a concept of global innovation networks: Chandler, Dunning, Cantwell, Pavitt & Patel are there, informing the intellectual roots of the concept.

Ernst also quoted a report by The Economist Intelligence Unit (2004) *Scattering the seeds of innovation*: *the globalization of Research and Development*, as a key source. A later EIU (2007) report is very often cited as the first reference to GINs (for instance OECD, 2008a), although it did not cite Ernst's (2006) earlier work. This report suggested that centralized R&D is increasingly being replaced by 'global innovation networks', but failed to distinguish between a number of different processes that may be occurring independently and simultaneously – the internationalization of R&D, relationship between firms and other external sources of technology, and changes in the management of TNCs. This business journal provides short and objective reports that highlight what are identified as new facts or phases in the world of technology, in a language adapted to the world of consultants and business people. For researchers of technology, the approach of *The Economist* can be taken as an empirical sign of changes in the world of technology. The work of Ernst and The Economist are thus seminal texts for an emerging research literature.

1.2.1 GINs and the Literature on Internationalization of R&D

The internationalization of innovation activities and the interaction between firms and external sources of technology - now branded as "open innovation" (OECD 2008b) – are processes that have been evolving and on the agenda of the economics of technology for some time.

The literature on the transnational and international distribution of innovative activities may be divided into three phases. A first phase surveyed by Caves (1996) includes papers and investigations until the beginning of the 1990s, which stress the strong correlation between R&D intensity and multinationality.[1] Analysis of this literature found that while the percentage of R&D performed abroad had increased over the past two decades the prevailing tendency was still for research to remain based at the headquarters of TNCs.

A second phase began in the 1990s, when the literature dealt with the increasing internationalization of transnationals' R&D activities. Examples of this line of research are OECD (1998) and special issues of Cambridge Journal of Economics (Technology and Innovation, February 1995) and of Research Policy (Internationalization of Industrial R&D, March 1999).[2] In an early work, Dunning (1995) identified four circumstances in which MNEs would engage in foreign-based R&D: for product or process improvements, research into basic materials or products, efficiency-seeking research to acquire foreign technological assets or to benefit from innovation activities. Decentralization of R&D is a process that is not so new, if one takes as reference the literature on transnational corporations. Kuemmerle (1997) investigated "global research networks", suggesting that qualitative changes take place in the course of this process. Kummerle (1997) suggested a distinction based on the direction of the technological flows. "Home base exploiting" foreign R&D flows to the foreign laboratory from the centralized R&D unit of the MNE, and "home base augmenting" foreign R&D flows to the central laboratory from foreign competitors and universities. Dunning (1995) speculated that such "home base augmenting" type of R&D would become more important over time and increase rapidly, attracted to countries with a more advanced technological

[1] This finding is very important to articulate the nature of NSIs and the presence of headquarters of TNCs – especially in the periphery.

[2] For a review of the literature on the first and second phases, see Biazzi & Albuquerque (2002).

and educational infrastructure.[3] Narin et al (1997) captured similar processes in their investigation of flows between science and technology, citing the contribution of local and foreign competitors and universities to IBM's patented knowledge as an example. During this phase, two new phenomena began to emerge: the rise of Asia and other peripheral regions, what UNCTAD calls developing and transition economies, and the role of talent pools as attractors of R&D-related FDI.[4]

The third phase is related to research on internationalization of R&D and the emergence of the concept of GINs (Ernst, 2006; The Economist Intelligence Unit, 2007; OECD, 2008a, 2008b).

Two reports from UNCTAD (2005, 2006) are examples of a transition between the second and third phases, since they deal with subjects that are typical of the third phase, but do not name them as 'global innovation networks'. UNCTAD (2005) showed how far the process of R&D internationalization had progressed, and highlighted the emergence of developing economies as locations for R&D.[5] It described the early stages of the rise of China as a location for foreign R&D, several examples of R&D international networks, such as Motorola or Toyota, and examples of R&D undertaken by subsidiaries of foreign affiliates in South Korea, Brazil, Morocco, Kenya and Czech Republic. While UNCTAD (2005) first reported the expansion of R&D abroad by developing countries' TNCs, by examining the cases of Chinese, Indian and Korean TNCs, UNCTAD (2006) evaluated the rise of TNCs from developing and transition economies.

1.2.2 GINs as a New Phase of Internationalization of Capital

Essentially, the contribution of this strand of the literature (Ernst, 2006; *The Economist Intelligence Unit*, 2007) is to identify a new phase in the history of global capital, of generalized changes that merit investigation. This is a process whose drivers have been explored since the investigations in the classics of political economy (Adam Smith, David Ricardo, John Stuart Mill and Karl Marx) - the push towards new regions and sectors to escape the curse of falling profits. Grossmann (1929) presents a broad overview of the mechanisms operating to counteract the falling rate of profit, and pinpoints the export of capital as one key mechanism. Exports of capital have carriers – the transnational corporations. There is a history of these movements (Dunning 1995) that over time grow in size and complexity. In 1857-1858, Marx had uncovered the complex and indispensable relationship between capital and science – it is possible to speculate that the international movements of capital may not happen alone, since they need science to operate. Marx wrote the *Grundrisse* and *Capital* in a time when the "technological application of science" was in a pre-historical period – the research on GINs and interactions points to what is necessary for today's capital movements across national borders.

Steindl (1976) in the revision of his stagnationist view of post war capitalism points to the underestimation of international flows of capital as an alternative channel for over-accumulation in the United States. Ellen Wood (2003) provides a good review of the classical literature on capital's

[3] According to UNCTAD (2005, p. 188), this asset-seeking FDI R&D-related creates more R&D linkages, establishing more connections with local universities.

[4] In two articles representative of the special issues of the *Cambridge Journal of Economics* and the *Research Policy*, Cantwell (1995) and Cantwell & Janne (1999) discuss only R&D located and relocated within developed countries. Taking Figure 2 as reference, this literature dealt only with the relationships between countries 1 and 2, at the capitalist center.

[5] UNCTAD (2005, p. 181) points to the connections between countries 1 and 3 in Figure 2.

push towards new regions: she highlights a new phase since the crisis of Bretton Woods, suggesting that "globalization" was an answer to problems at the center of capitalism, based on the analysis of Robert Brenner (2006) about the long downturn of US capitalism.

These processes have been investigated by contemporary researchers investigating interconnected phenomena, sometimes using other terms, such as global industries (Macher & Mowery, 2008); international value chains (Linden et al, 2007); or internationalization of labor markets (Richard Freeman, 2007).

The conceptual elaboration of GINs has evolved over the past few years. Ernst's (2009) later work dealt more critically and in a better informed way with issues such as the emergence and diffusion of GINs. GINs emerge as a natural expansion of global production networks and share their three defining characteristics. A first common feature is "asymmetry" (Ernst & Naughton, 2008), given that the hierarchy between firms, countries and regions impacts on and is preserved within GINs. Global firms create GINs to take advantage of the rise of global markets for technology, in order to increase return on investment by penetrating high-growth emerging markets. One important clarification is the dominant role of leading firms – termed network flagships - in the formation of GINs and in determining the nature of networks.

Ernst (2009) thus argued that GINs can be a "mixed blessing", with negative effects on less developed countries. The global centers of excellence remain located in the United States, Japan and European Union, which are able to retain their dominant position and control over the "emerging new geography of knowledge". The new global hierarchy is characterized by a distinction between "global centers of excellence", "advanced locations", "catching-up locations" and "'new frontier' locations".

A second common feature of GINs and GPNs is that a variety of governance structures are found, ranging from loose linkages to highly formalised networks. And a third feature is that knowledge sharing is at the core of networks. The flagship firms in the network gain access to skills and capabilities but more significantly, they may access new ideas, models and processes. An important contribution of this work is the development of a "taxonomy" of five types of GINs based on the analysis of Asian firms (Ernst 2009):

1. Intrafirm networks, in which TNCs 'offshore' stages of innovation to their Asian subsidiaries,[6] characterized typically by an inequality in the division of innovation tasks[7], for example, Texas Instruments, Cisco and Intel, with labs in Bangalore
2. Interfirm networks, in which TNCs 'outsource' stages of innovation to specialized Asian suppliers, for example, Hewlett-Packard, Dell, Acer and Lenovo use design services provided by firms from Taiwan
3. Networks of Asian flagship companies, in which Asian firms develop their own networks, mostly intrafirm but increasingly, located in developed economies, for example Chinese Mobile, MediaTek Taiwan or Huawei
4. International public-corporate R&D consortia

[6] UNCTAD (2005, p. 104, Box III.2) defines three categories of internationalization of innovation. Its third category – "international generation of innovations" – would fit this "type" of Ernst's taxonomy. The UNCTAD's report is clear about the role of TNCs: "the TNC is the only institution that, by definition, can control and carry out within its boundaries the process of innovation across the globe" (p. 104).

[7] UNCTAD (2005, pp. 173-177).

5. Informal social networks of students and other knowledge workers

1.2.3 Disentangling the concept of GINs

This literature intertwines diverse factors that operate in the present transition towards a new phase of capitalism. The emergence of GINs is related to a broader global context that may be characterized by academic discussions on the decline of US hegemony, as put forward by Arrighi (2007). Arrighi's view has been subjected to huge criticisms, and the discussion about his global diagnosis help to prepare an evaluation of the present challenges and changes (see the special issue of *Historical Materialism* on Arrighi's work on China). On the other hand, the investigation of GINs contributes to a better understanding of the changes under way in the broader global context.

What are the factors that contribute to the emergence of GINs?

First is a new stage in the nature of transnational corporations, the "dominant R&D players" (UNCTAD, 2005:119), as they are one key 'driver' of the emergence of GINs (Ernst, 2006; 2009). Dunning (2008) highlighted how TNCs reshape the international division of labor. One change is the emergence of TNCs with headquarters at the periphery (UNCTAD, 2006), which construct their own GINs as in type 3 GIN of Ernst's taxonomy (2009).

A second factor is the emergence of new technologies, the ICT revolution. It is noteworthy that the case study of Ernest's pioneering research is chip design (Ernst, 2006). Similarly, Linden et al (2007)'s research focuses on PCs, Apple, and iPods. A report on *Innovation in global industries* (Macher & Mowery, 2008) evaluates only high-technology sectors such as PCs, software, pharmaceuticals, biotechnology and flat panels. The ICT revolution enhances the mobility of innovation (Ernst, 2006).

Third is the emergence of Asia as an economic power and new destination for foreign R&D, especially China and India (*The Economist Intelligence Unit* 2007). The rise of East Asia has potential implications that have been explored by Arrighi (2007). In an important book on China, Naughton (2007) identified a process of deeper integration into global production networks that includes R&D outsourcing and internationalization of innovation as a source of opportunities. Through a case study of Lenovo's outsourcing of its laptops and PDAs, Naughton raised the question whether these initiatives could turn the international model of subcontracting around. Therefore, the issue is not only the emergence of Asia, but the risk of broader hierarchical changes in the global economy. Beyond Asia, the emergence of other locations like Brazil, South Africa or Mexico is a specific characteristic of this new phase.

Fourth, are the changes in the relationship between firms and other external sources of innovation, or the trend towards "open innovation" (OECD 2008b). This is an old subject in the literature of innovation, and important for understanding the international movements of TNCs. There is an intensification of what has been an important feature of innovation - that firms do not innovate alone - which becomes more visible when the arena is the world.

Fifth, globalization is sometimes understood as the liberalization of capital flows throughout the world or as a process driven by liberalization. Ernst (2006) stressed that liberalization has been a catalyst for the expansion of global production and innovation networks. This is a naïve view of the globalization process. Liberalisation has determinants that goes beyond strictly economic factors. Wood (2003) has highlighted the role of states (especially the government of the United States) as key actors driving this phase of "internationalization of market imperatives". According to Wood

(2003: 139), the state "has created the conditions enabling global capital to survive and to navigate the world" (see also Panitch & Gindin, 2005).

A sixth factor that is intertwined with the emergence of GINs is changes in the international division of labor – a continuous historical process, pushed by international movements of capital (for a broader view, see Silver, 2003). Currently, the relocation of capital, of manufacturing and of R&D activities have driven the internationalization of R&D and GINs. There is also an increasing division of labor in innovation (Ernst, 2009) that in turn, is another driver of GINs. These changes in the international division of labor have highlighted concern about the future of the hierarchy within the international division of labor. There are those who argue that the repositioning of labor internationally may not subvert the existing hierarchy, a point that has not been emphasized in the literature (Ernst, 2006; Macher & Mowery, 2008; Jefferson, 2007).[8]

Seventh, are the educational consequences of the processes of formation of national systems of innovation at the periphery. The engineering and scientific resources available in countries like China and India opens new options for TNCs – to hire specialized people with lower wages (Freeman, 2005; see also Ernst, 2006). This seems to be the real novelty of the GIN approach, particularly the new location of this talent pool. In the case of China, Sun (2002) and Spence (1990) stressed the role of one of the "four modernizations" defined by Deng Xiao Ping, in the late 1970s: science and technology as a "productive force", and the plan to train 800,000 "scientific workers" (Spence, 1990: 611).

Theoretically disentangling these seven different factors impacting on the nature of GINs was necessary, in order to deal with our specific focus – interactions in a global context.

1.3 INTERACTION WITH UNIVERSITIES AND GINs

The paper began by postulating that although the two strands of literature of innovation - on interaction and on GINs - both mention universities and foreign corporations, neither conceptualises the two concepts together in a systematic manner as core research focus.

On the one hand, Klevorick et al (1995) and Cohen et al (2002) investigate firms interacting with universities. Some of these firms may be headquarters of TNCs, for instance, an investigation of IBM and its knowledge flows (Narin et al 1997). In general, however, this literature tends to investigate interaction within a single country and limited by national boundaries.

On the other hand, universities are typically seen as important for the emergence of GINs, but there is little direct focus in the research on their role. The literature on GINs points to the role of the talent pool available in peripheral countries as one key driver of GINs (Ernst, 2006; *The Economist Intelligence Unit*, 2007). It may consider the importance of universities for GINs, and the entanglement between GINs and "open innovation", for which universities and research institutes are important external sources of knowledge, but not as a core focus of investigation.

[8] Jefferson suggests that the movements related to GPNs and GINs only reshape the international division of labor while preserving the technological hierarchies. According to him, "[j]ust as the phenomenon of FDI and R&D offshoring leads to spillovers that induce Chinese firms to establish rudimentary operations, the same pattern of offshoring is also motivating the United States and other OECD MNEs to upgrade and diversify their R&D operations in order to maintain control the development and deployment of critical technologies" (Jefferson, 2007, p. 213)

This section thus evaluates how each strand of the literature on innovation deals with the issue that is not at its core – how the literature on firm interaction with universities deals with the globalization of R&D, and how the literature on GINs deals with the role of universities.

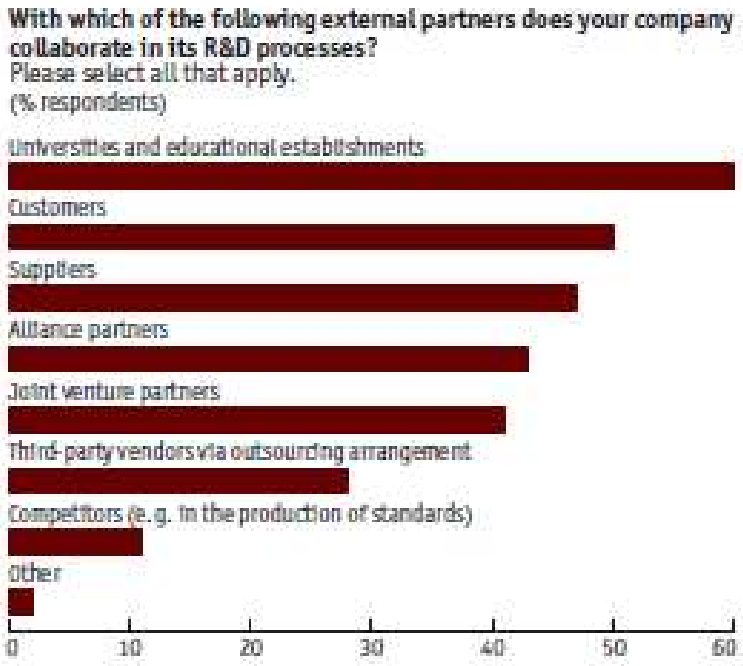
1.3.1 References to Universities in the GINs' Literature

The literature on GINs definitely displays awareness of the significant relationship between GINs and universities and research institutes, but this is typically implicit and largely unexplored.

In the earliest literature, elaboration of the external partners that collaborate with global companies in their R&D processes included universities alongside customers, suppliers, alliance partners, joint-venture partners and so on. Kummerle (1997) pointed to foreign universities as targets for "home base augmenting" foreign R&D. A survey of 300 executives (*The Economist Intelligence Unit*, 2007) highlighted the significance of universities and educational establishments, which were reported as the most frequent collaboration partners, for 60% of respondents (Figure 1.1.).

Figure 1.1

GINs and External Partners



Source: *The Economist Intelligence Unit* (2007, p. 10)

Likewise, an OECD (2008b) report aimed to show how the use of external sources of technology is increasing and goes hand-in-hand with global innovation networks. Universities and research

institutes are identified as critical sources of innovation, so that there is a growing trend towards the globalization of industry-science relationships. One mechanism was the establishment of units to identify potentially interesting R&D at universities. Another was new financial arrangements, corporate venture capital divisions (Gompers & Lerner, 2001), to access new ideas through joint ventures, acquisitions or university-based collaborations. Thus, at least three out of six reasons for major companies to invest in R&D in China were related to universities – the pool of talent available, the pursuit of private funding sources by universities and research institutes, and the possibilities of accessing new innovations and entering into IPR agreements (UNCTAD, 2005).

The shift from in-house, centralized R&D units towards strategic alliances with other firms or universities is stronger in certain sectors such as pharmaceuticals, given that a single company cannot have expertise in all the research areas required for developing new products (UNCTAD 2005). The literature is replete with examples from other sectors, taking different forms. Examples of collaboration between foreign affiliates and local universities range from Microsoft Asia in partnerships with Chinese universities, Intel which reports 250 sponsored research projects and STMicroeletronics which has a training center in Rabat, Morocco (UNCTAD 2005). Examples of Asian firms that have established GINs with amongst others, universities in the USA and Europe include China's Huawei (Ernst& Naughton, 2008) and Taiwan's TSCM (Ernst, 2009). Type three of Ernst's (2009) taxonomy specifically mentions universities only with regard to these Asian firms GINs. Of course, in the two first types (intrafirm and interfirm), the direct and/or indirect links with universities are implicit, given the previous formulations of Dunning (1995) and Kummerle (1997) incorporated in Ernst's elaboration. Ernst's type four GIN, international public/corporate R&D consortia is not well elaborated or exemplified, but it has strong parallels with the category of "internationalization of innovation" that involves universities, public research centers, national firms and TNCs (UNCTAD, 2005). It is not difficult to identify actual examples, such as EUCAGEN (Eucalyptus Genome Research), involving 82 public and private institutions, including a Brazilian firm, Fibria (Penchel, 2008).

This literature thus emphasizes the significance of universities and public research institutes in the formation of different types of GIN, but in a peripheral way. It focuses on firm strategies and does not elaborate on the nature of interaction or the role of universities in national systems of innovation in any depth.

1.3.2 References to International Networks in the Literature on Interaction

In contrast, Ernst (2002) has highlighted the shift towards the decentralization of R&D in the last decades, and criticized the literature on the national system of innovation for its neglect of the international dimension. Other papers on the internationalization of national systems of innovation recognise the limited focus of this literature beyond national boundaries (Carlsson, 2006). The criticism is correct, but it somewhat overstates the case. If we read the literature on national systems of innovation carefully, we find instances of research on internationalization, even if authors related to the evolutionary approach emphasize the relative slower trend towards the globalization of technology, vis-à-vis finance and production (Cantwell, 1995; Patel, 1995).

If we look closer and go beyond the more popular side of evolutionary papers, we can find important clues to the relevance of the international dimension – at least implicitly. Science is international, by definition (Zitt et al, 2004). A key subject investigated by the evolutionary approach – catch up processes – highlights the importance of international contacts and access to

foreign knowledge. Every description of a successful catch up process necessarily deals with flows of foreign technology and science. One very simple suggestion would be to re-read Nelson's book on national systems of innovation (1993) and take notes about how each country – when it was emerging to take technological leadership – designed creative ways to access and use knowledge available elsewhere: Germany learned from the UK; the US learned from Germany; Japan learned from Germany, England and US; Korea learned from Japan and the US. Students sent abroad, engineers invited to create faculties, foreign engineers hired to run new firms, factories bought, visits to top firms and top universities: various different ways were designed to absorb knowledge available elsewhere.

Other research suggests that changes in the international scenario impacts the fate of (important) NSIs, as the case of the US after post-war European and Japanese catch up suggests (see Nelson & Wright 1992). TNCs matter (Chesnais, 1988, 1994). Studies of international alliances and cooperation show how connections between different NSIs are established (Hagedoorn, 2002; Ostry & Nelson, 1995).

Scientific infrastructure may be an important attractor of foreign firms (Pavitt, 1991). In an investigation of the levels of and changes in foreign R&D of US TNCs, Patel (1995) found that the firms that most internationalized their R&D were in the beverage and tobacco, food, building materials, other transport, pharmaceuticals, and mining and petroleum sectors. These are not sectors typically characterized as high technology, nor are they typically associated with a global mandate as are computers or automotive sectors (except for pharmaceuticals). Most of the R&D activities related to localized adaptation to take into account differences in consumer tastes and government regulations or to exploit local natural resources. Patel proposed that the firms with higher R&D intensity were internationalizing technological activity to a lesser extent, because production and R&D were required to be in close proximity to one another.

Patel's research is a useful identification of changes over time. Since 1995, as Ernst has suggested, there has been a rise of internationalization of high-tech sectors. Furthermore, Patel pointed to specific reasons that lead to the internationalization of R&D in sectors like food, mining and petroleum that are still operating currently. As time goes by, the nature of foreign R&D activities becomes more complex.

The lack of focus on the international dimension of national systems of innovation is thus not inherent to the approach, and is conceptually possible. What is the role of the university as elaborated in the national system of innovation literature, that can add to a synthesis with the literature on GINs?

1.3.3 The Changing Role of Universities at the Periphery[9]

The nature of technological progress in capitalism was discussed by Marx (1867), showing how a permanent revolution of the technological base is a key factor of capitalism. Later, Schumpeter (1939), Mandel (1974) and Freeman (1982) have shown how through long waves of capitalist development, technological revolutions shape and reshape the structures of the capitalist economy. The literature on interaction between science and technology in developed countries could be read as explaining how these technological revolutions are generated from the center. The technological

[9] This sub-section is based on Suzigan et al (2009).

revolutions generated at the center of capitalism are diffused throughout the whole world and impact on 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 illuminates the standpoint from which we investigate the interaction between universities and firms: at the periphery, a part of the world where technological progress generated at the center impacts and determines the position of countries in the international division of labor.[10] The impacts 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 universities at the periphery establish their first role: universities might be an important channel to absorb knowledge generated abroad from the center of technological dynamics. It implies that the tasks of universities and firms related to knowledge absorption are ever changing.

Universities and PRIs are one of the first channels to connect a country at the periphery to the international flows of science and technology.[11] Their first universities and PRIs were created with foreign teachers and/or local students that graduated abroad.

Late development, by definition, means high levels of poverty, inequality, strong social problems such as 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, on the one hand, keep in touch with scientific and technological development at the center while, on the other hand, they will face local problems and issues (diseases, soils, plant varieties, geological conditions) that need specific investigation and might generate new scientific knowledge.

Furthermore, there are various tasks to be performed by universities/PRIs: teaching, training of human resources to populate public administration (specially at the beginning of the nation building process) and to create the first firms (sometimes 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, a kind of wave of institutional formation seems to be an empirical regularity, with new PRIs and universities (or at least faculties) that may help to solve new and more complex problems. 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 harm harvests, from mining sectors to up-grade mining techniques, there may be demands from governments to provide tests for infrastructure building. There also may be institutional building ahead of demand that later should foster the creation of new industrial sectors and/or provide engineers to work in transnational corporations moving to that country.

No matter what 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 dynamic is the attempt to preserve links with the evolving S&T international environment.

[10] 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).
[11] Other forms of early connections to developed countries are travelers, traders, and study abroad.

The growth of universities and PRIs and consequent diversification is itself a process with social resistance and not easy. Size, diversity and quality of universities depend upon 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 create limitations in the role of universities for development.

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 National Agricultural Research Systems (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.

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 are specific forms of relationship. Eun et al (2006) suggest that these modes of interaction are specific for a context of universities with 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 spin-off. This Chinese specificity, as Eun (2005) explains, has historical roots that can be traced back to 1949, the foundation of PRC. Eun mentions "three major peaks of academic-run enterprise development", during the Great Leap Forward, during the Cultural Revolution and after Deng's reforms (especially the S&T reforms). Lenovo, one of the Asian GINs studied by Ernst (2009), was created as university-run enterprise, showing how a firm spun-off from a local university (therefore, already plugged into a network of knowledge) then becomes independent of that local university and finally establishes interactions directly with other universities abroad.

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) - or what Eun et al (2006) call universities' capabilities develop.

1.4 A TENTATIVE SYNTHESIS: GLOBAL INTERACTIONS BETWEEN FIRMS AND UNIVERSITIES

The arguments presented in Sections 1.2 and 1.3 suggest that GINs have not one, but two main drivers. First, are the TNCs and their growing capabilities, technological and locational diversity, as they move across the world selecting locations and distributing productive and innovative labour. Second, the formation and growing complexity of national systems of innovation, especially at the periphery, is a process that goes far beyond the limited push of capital towards new regions and sectors. One important engine of this process is the internationalization of science. The formation of NSIs involves political forces that shape states and their autonomy, capabilities and public resources to generate and support their public institutions. For example, the rise of talent pools is a consequence of investments in science and engineering that shape NSIs. Therefore, there are two movements reshaping and reorganizing the international division of labor. This reshaping of the

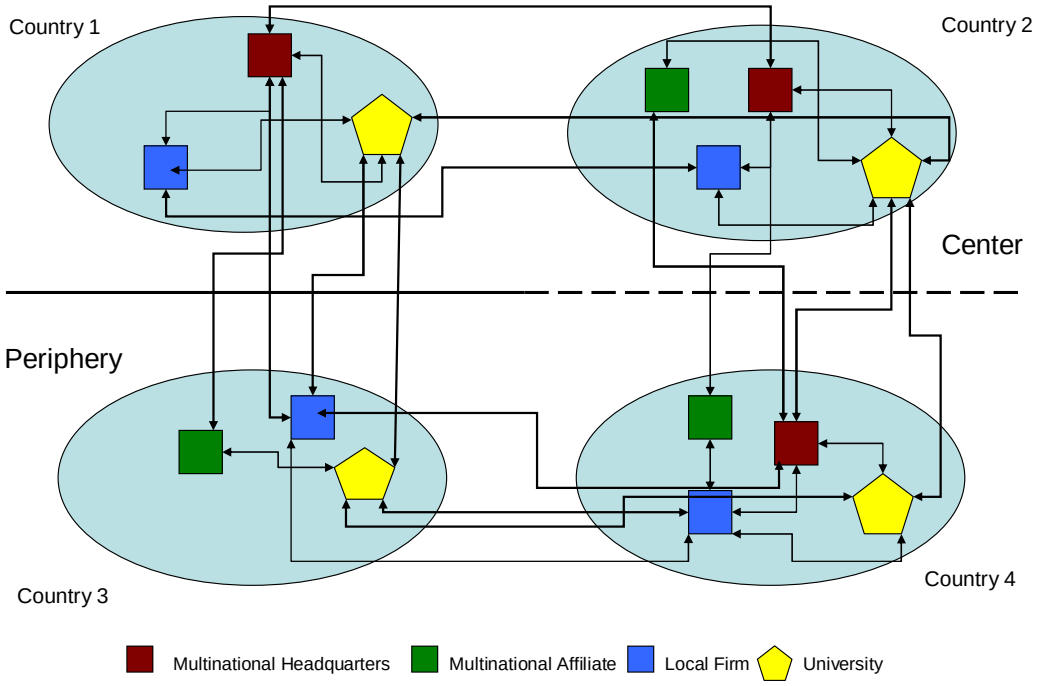
international division of labor, in turn, affects the internal decisions of TNCs and the actions of their subsidiaries, pushing further changes in the international division of innovative labor.

The combination of these two drivers leads to a complex picture, where the nature of NSIs matters for the formation of networks, their main characteristics and the nature and scope of the international hierarchies established, which will be the subject of the concluding Section 1.5 of this paper.

A tentative framework to synthesise these insights is suggested in Figure 1.2. Firms - local and TNCs - universities and their links, are reflected in a hierarchical world, divided between a center and a periphery (Furtado, 1982), and the implicit social and political forces that shape NSIs defining the major countries' characteristics and possibilities within a global innovation system in the making.

Figure 1.2

Global Interactions between Firms and Universities - A Tentative Framework



Source: authors' elaboration, following a review of the literature (see section III).

Figure 1.2 reflects a division between center and periphery. But this divide has two features: the first is portrayed as a continuous line, the other as a discontinuous line. The difference is intended to express graphically the possibility of catch up – the emergence of a country that successfully overcomes underdevelopment. The case of South Korea during the 1980s and 1990s is a case in point, the inescapable goal of all serious technological policies.

The framework in Figure 1.2 is based on the two strands of the literature discussed in the previous sections. The main contributions that underpin the logic of the framework are summarized and reiterated here.

The starting point is work that conceptualizes the interactions between firms and universities in developed countries, based on interactions within a single country (Klevorick et al 1995, Cohen et al 2002). These are reflected in Country 1 in Figure 1.2. This work has been elaborated to examine the interactions between firms and universities in developing countries, again, interaction within national boundaries, but which may include TNCs's subsidiaries in those countries (Rapini et al, 2009, Lee et al, 2009, Kruss, 2009). These are reflected in Country 3 in Figure 1.2.

A similar limited set of interactions are suggested by Patel and Pavitt (1998), who are very cautious on the internationalization of innovation. They stressed the ways in which firms in developed countries may use other countries' scientific infrastructure as sources of information, where national systems are not able to meet the needs of innovating firms. These are represented as interactions between TNCs in country 2 and universities in country 1 or vice versa.

A critical work that links the two strands is the UNCTAD (2005) study that demonstrates the chain of TNC connections between developed and developing countries, linking countries 1 and 3 in Figure 1.2. Ernst's (2009) taxonomy of GINs, specifically types 1 and 2, further informs the elaboration of these links (between countries 1 and 3).

However, Ernst's (2009) elaboration of a type 3 GIN, of a TNC based in a country at the periphery and interacting with universities at the center, has informed the elaboration of the framework. This is reflected as the connections between a TNC with headquarters in country 3 or 4 and its subsidiaries in country 2 and universities in country 1 or 2. Likewise, Azevedo (2009) analysed a transnational firm based in a peripheral country that has research collaboration with 70 universities and research centers abroad (a firm from country 3 interacting with universities in countries 1 and 2 – or multiple countries at the center).

OECD (2008b) research on Japanese TNCs and their networks with universities in China, India, Japan, and the US illustrates a different set of possible connections between TNC headquarters, TNC subsidiaries (including in the US) and universities. These are reflected as connections between country 1 and 2 and between country 1 and country 3 and/or 4 in Figure 1.2.

The literature also highlights a growing trend towards connections between firms based in different countries at the periphery, for instance, biotechnology inter-firm networks (Thorsteinsdóttir 2010). Those firms were typically born as spin-offs of local university research, with their international connections. These are represented as connections between local firms in country 3 and local firms in country 4.

The significance of connections between the universities – the science networks – is also included in the framework. There are strong "engines of internationalization" of science, old and new (Zitt et al 2004).[12] For developing and catch up countries, the networks of science and related educational

[12] The engines of science internationalization are, according to Zitt et al (2004): 1) "History of science teaches that scientists consider it natural and profitable to freely communicate and collaborate, and professionalisation of science in the XIXth and XXth centuries has fostered this trend. This self-organisation is the first engine of science inernationalisation" (p. 408). 2) "multinational programmes" common after the WWII – "top down processes and self-organisation interact in many ways in large scale programs" (pp. 408-409); 3) "general movements of financial and economic globalization" – "R&D services' implementation and their articulation with local research are often viewed as

investments may be the first networks to be established, to connect one country with the global knowledge networks centered in the leading countries. Examples are global research consortia such as the *International Human Genome Sequencing Consortium*, with research institutes from the US, China, France, Germany, Japan participating. It is important not to underestimate these scientific networks, as discussed in section 2.3. These scientific networks connect all four countries in Figure 1.2.

Supported by this literature, Figure 1.2 graphically represents a tentative framework to deal with global interactions between firms and universities. This framework would yield four main types of interaction, with variations depending on their location in the centre or periphery, which necessarily go beyond GINs, both backwards and forwards:

1. LOCAL firms interacting with local and/or foreign universities
    a. in the north
    b. in the south
2. TNCs interacting only with their LOCAL home based universities
    a. in the north
    b. in the south
3. TNCs interacting both with LOCAL home based universities and FOREIGN universities in a host country/ies
    a. from the north
    b. from the South
4. INTERNATIONAL consortia between firms and networks of universities

These main types are elaborated in the following paragraphs.

TYPE 1 – ONLY LOCAL INTERACTIONS. These are interactions between local firms and local universities. This type does not involve cross-border transfer of knowledge. It could represent the first step for a firm to become transnational. That is, it allows for an initial accumulation of knowledge and capabilities that supports a transition from being a local to a transnational firm, since there is a deep correlation between transnationality and R&D-intensity (Caves, 1996). In Figure 1.2, these are represented as the relationships between firms and universities within each country. In earlier stages of capitalism at the center, they could be the typical and most advanced interactions with universities. Now, this type of interaction may be located in firms at the periphery – within countries 3 and 4.

Interactions between local firms and foreign universities, are the first and simplest form of cross-border transfer of knowledge. In Figure 1.2, this flow would connect a local firm in country 1 and a university in country 2. Local firms would typically interact both with universities in their home countries and with foreign universities. Historically, this type would have first connected developed countries (countries 1 and 2). Currently, this type of interaction would be important for local firms at the periphery looking for knowledge that the local science infrastructure would not be able to

an important internationalization engine"; 4) the ICT revolution and the explosion of electronic networks have "boosted non-physical exchanges and especially scientific work" (p. 409).

provide. In Figure 1.2, this is represented as a connection between a local firm in country 3 and a university in country 1.

TYPE 2: TRANSNATIONALS INTERACTING ONLY WITH HOME COUNTRY UNIVERSITIES. This would be the typical relationship reported in the literature on internationalization of R&D. The TNCs have connections with their home country universities, but the host countries either do not have R&D activities or the R&D activities are completely centralized at the TNC headquarters.

TYPE 3: TRANSNATIONALS INTERACTING BOTH WITH HOME COUNTRY AND HOST COUNTRY UNIVERSITIES. This would be the more recent pattern of interaction. There is a broader division of innovative labor within the TNC, with the possibility that a subsidiary assumes contacts and performs contracts with the host country university. The nature of this relationship will depend on the nature of the subsidiary's role within the TNC, ranging from limited adaptive activities – that would require contacts with local laboratories or engineering departments – to more advanced projects – that would involve R&D joint research with local universities, sometimes in connection with foreign universities too. The hierarchy and the decision-making about the specific roles of home-country and host countries R&D departments may vary deeply, and this variety should be incorporated within this type.

Firms (local or transnational) may establish contact with one specific university (local or foreign) but would take advantage of the other universities (local or foreign) that are linked to the first university through their existing scientific and educational links. This is important, given the natural trend to the internationalization of science, with its formal and informal links. The interactions of firms with networks already established among universities are rich in multidirectional knowledge flows.

TYPE 4: INTERNATIONAL CONSORTIA BETWEEN FIRMS AND UNIVERSITIES. This type involves firms, universities and research institutions, but they might be proposed and coordinated by the academic side of the interaction. Intergovernmental cooperation and international institutions, such as WHO, could trigger this kind of interaction. They could be "mission-oriented" and necessarily non-hierarchical. They also could be a characteristic of a global innovation system.

A fifth type is possible, but not yet existent – a non-hierarchical network between TNC headquarters and subsidiaries and their connections with universities. Asymmetry and hierarchy are "defining characteristics of both previous GPNs and existing GINs" (Ernst, 2009). This type must be included to benchmark prevailing international networks - it could be seen as the desired feature of a global innovation system, and poses a challenge to policy that will be discussed in Section 1.5.

These four main types elaborated on the basis of the framework attempt to summarize the full range of interactions, but they certainly do not cover all possibilities. Many real world cases would be mixed cases. For example, the formation of international networks that may combine interactions at TNC headquarters that have interfirm connections with local firms in a foreign country, and this local firm may have interactions with local universities. Another example is a TNC that establishes contacts with foreign universities either in countries where it does not have a subsidiary or directly with a foreign university, bypassing its local subsidiary.

There are two differences with Ernst's taxonomy that deserve comment.

First, the taxonomy elaborated here does not differentiate the home country of a TNC. A TNC with headquarters in peripheral country 4 and a subsidiary in country 2, with connections both with local

and foreign universities is a type 3 interaction, equivalent to a TNC with headquarters in country 1 at the centre and a subsidiary in country 3. Over time, what changes is the appearance of TNCs based in peripheral countries (UNCTAD 2006).

Second, this taxonomy does not include a type of relationship that includes informal contacts – Ernst's "informal social networks". On the one hand, according to the literature on interactions, informal contacts constitute one very important source of information even in developed countries (Cohen et al, 2002). On the other hand, students sent abroad, brain drain and brain gain movements are part of the dynamics of internationalization of science that could be described in Figure 1.2 as direct contacts between universities from the four countries. Since this taxonomy is designed to describe global interactions between firms and universities, these movements within the scientific networks are not defined as a separate type. However, as discussed in previous sections, these movements with the scientific networks are very important to the constitution of global interactions. In fact, they are an essential precondition, it must be emphasized.

All of the changes in globalization of interactions discussed in previous sections can be evaluated using this taxonomy, which is necessarily static. However, it can be elaborated to deal with a deeply dynamic environment. TNCs from developing countries are a new phenomenon. Therefore, if Figure 1.2 were drawn to represent dynamics in the early 1950s, the arrow connecting a TNC headquarter in country 4 and its subsidiary in country 2 would not exist. Furthermore, the discontinuous line between the center and the periphery, between countries 2 and 4, opens up the possibility for catching up processes and for the overcoming of underdevelopment.

Another important dynamic feature is pointed to by the literature on networks. That is, "networks and innovation constitute a virtuous cycle" (Powell & Grodal 2005: 67). The knowledge exchanges and trust built during collaborative work and the achievements of the network, means that over time, networks may become less hierarchical. In sum, these network improvements over time must be incorporated in the taxonomy.

Finally, the taxonomy includes the empirical regularities unveiled by the literature on interactions (Cohen et al, 2002) and transnationals (Dunning, 1995) regarding sectoral specificities.

The integration between the literatures on GINs and on interactions between firms and universities, and the synthesis of a framework to characterise global interactions between firms and universities has an important theoretical consequence: the subject of the interdependence between national systems of innovation is clearly on the agenda.

1.5 INTERACTIONS, NSIs AND TNCs: IMPLICATIONS FOR THE PERIPHERY

The framework presented in section III shows a connection between different NSIs – each country represents one NSI. From this standpoint, there is a direct relationship between the country's position in the international division of labor and the nature of their NSI.

There is a hierarchy in this international division of labor, as the strucutralist tradition has put forward with the elaboration on the center-periphery divide (Furtado, 1982). This divide has become more complex and nuanced over time, a consequence of industrialization processes (Amsden, 2001), formation of NSIs at the periphery (UNIDO, 2005), and successful catch up processes (Amsden, 1989; Wade, 1990).

Using statistics of science and technology, Ribeiro et al (2006) divided the world into three different "regimes", and the periphery is divided between two of these.[13]

The maturation of NSIs may change the hierarchy of countries, and reorganize the international division of labor. But changes in the global hierarchy of NSIs are not easy. There are changes that only reinforce the nature of the dependency processes, with a modernization of the dependency structures (Furtado, 1982). Upgrading of industrial structures through the impact of technological revolutions at the center may only reshape existing structural problems in less-developed countries: there is a polarity of "modernization-marginalization" that is typical of underdevelopment (Albuquerque, 2007).

The changing nature of the center-periphery divide (Ribeiro et al, 2006) may be characterised by a "Red Queen Effect": countries at the periphery may run fast just to preserve their position in the international hierarchy of countries. Seen from the center, policies to sustain technological leadership are necessary (Macher & Mowery, 2008; Ernst, 2009).

There are global elements in (national) systems of innovation: at least one factor among the starting points of each national system of innovation is international. The taxonomy presented in section III highlights multifarious flows and links that create interdependence between NSIs.

However, participation within GINs depends both on the actions of TNCs and on the structural characteristics of the country shaped by its NSI. In other words, there are educational, industrial, scientific, public policies preconditions to join GINs, dependent on previous investments in the formation of its NSI.On the one hand, the industrial landscape of a country is determined by the capabilities of its domestic firms and of its home-based TNCs. On the other hand, the quality of its country scientific infrastructure will define the kind of assets that a TNCs may seek within its borders.

Ernst`s (2009) evaluation of the role of asymmetry and hierarchy within both intrafirm and interfirm GINs suggests that one way to escape subordinate roles in GINs hierarchies is to own the flagship corporation that shapes the international network – as is increasingly evident (UNCTAD 2010). Therefore, formation of home-based transnational corporations is one key policy objective (Ernst & Naughton, 2008). Furthermore, BRIC's countries acquisitions of foreign firms are increasing as another strategy (UNCTAD, 2010). In the formation of home-based TNCs, peripheral countries have challenges and opportunities. Public policies need, to combine the old process of NSI formation and improvement with new challenges and opportunities opened by GINs and current changes in the world.

The TNC core sector depends on the strengths and specializations of each country's NSI. A list of top 100 non-financial developing and transition economies TNCs[14] shows this correlation with its home base specialization. Brazil has three TNCs in this list, related to its strengths in mining, petroleum and steel. Taiwan, with fourteen companies in the list, has nine in the "electric and electronic sector". Korea, with five companies, has two in the "electric and electronic sector". In

[13] In this division, Korea and Taiwan are in the group of leading countries – both countries have joined this group in 1998, according to Ribeiro et al (2006), leaving an intermediate level populated by countries as Brazil, South Africa, Mexico, India and China. Therefore, there is a difference between Ribeiro et al (2006) and UNCTAD (2006), since for UNCTAD Korea and Taiwan still are "developing economies".

[14] See http://www.unctad.org/sections/dite_dir/docs/wir2010_anxtab27.xls.

sum: the NSIs position within the international division of labor also determines the nature of the country's TNCs, which, in turn, shapes one important feature of the country's involvement in GINs.

The theoretical framework presented in section III, particularly the proposition that both TNCs and the processes of NSI formation shape GINs, has one important implication for peripheral countries: the nature of NSIs shapes the national role in existing GINs. Therefore, immature NSIs will have immature (or incomplete) GINs – the limits of the NSIs will be reflected in sectors and nature of these GINs.

This leads to one simple conclusion – investment in the formation of NSIs is crucial as a guarantee of a less subordinate role in an emerging global system of innovation. This process of formation and improvement, with growing global connections and interactions, is a precondition for a more equal world, where the overcoming of the center-periphery divide is a real global goal.

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CHAPTER 2: SCIENCE AND TECHNOLOGY INDICATORS AND THE INTERNATIONAL POSITION OF SOUTH AFRICA AND BRAZIL

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2.1 INTRODUCTION

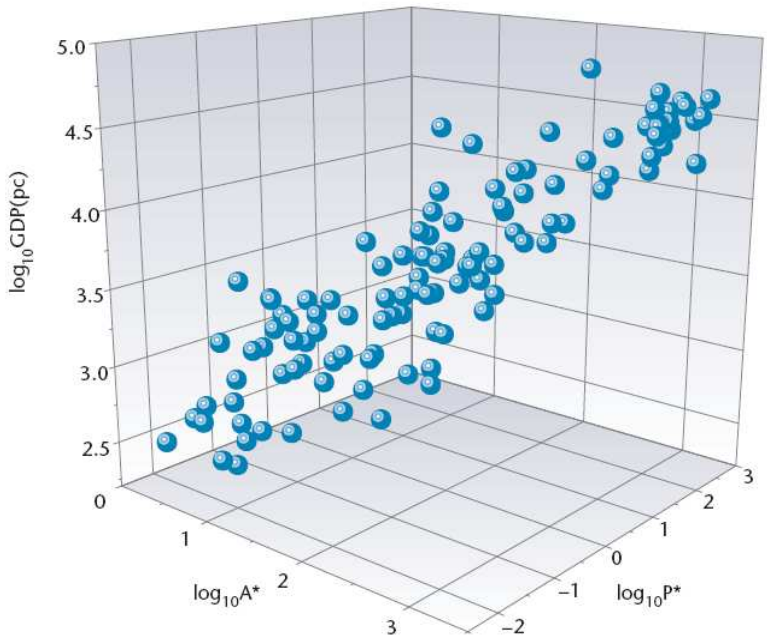
How do South Africa and Brazil participate in global interactions between firms and universities? This is a key question for this Report. In this chapter a preliminary discussion of this position is presented. Two topics matter, for this objective: in what "regime of interaction" between science and technology are South Africa and Brazil, and which are the South African and Brazilian transnationals (who and where are they).

2.2 SOUTH AFRICA, BRAZIL AND THE "RED QUEEN EFFECT"

Ribeiro et al (2006) analyse data on scientific articles and patents for several countries and for a period of thirty years. Although the numbers of scientific articles published and patents applied for are not perfect measures of scientific production and technological capabilities, these quantities are used extensively in the literature. We therefore believe that they furnish a worthy and simple way to compare countries and their NSIs. For a critical discussion of technological measures, see reference 11. For the years 1974, 1982, 1990 and 1998 we use the data from Bernardes & Albuquerque (2003). That sample incorporates developed, developing, and catching up countries, the later ones are countries that have begun their process in the group of less developed countries and have ended up by achieving a position near the more developed ones. The data on GDP per capita, patents and scientific papers were collected by the World Bank, USPTO, and Institute for Scientific Information. Only data for the so-called hard and applied sciences were used. Since scientific production and patents vary from one period to another, the number of countries in the sample changes. The largest data set is for the period 1999-2003 (183 countries are in our database, 61 countries have zero patents, 8 countries with zero papers and 8 countries without available GDP). Figure 2.1 shows a three-dimensional plot of patents per million of inhabitants (P*), articles per million of inhabitants (A*), and per-capita GDP, for 119 countries with scores different from zero. Figure 2.1 suggests a strong correlation between science, technology and income.

Figure 2.1

Plot of $\log_{10}$(GDP per capita - 2003) *versus* $\log_{10}$A* (articles per million of inhabitants) *versus* $\log_{10}$P* (patents per million of inhabitants). The data for arti*cles* and patents represent an average for the years 1999-2003.

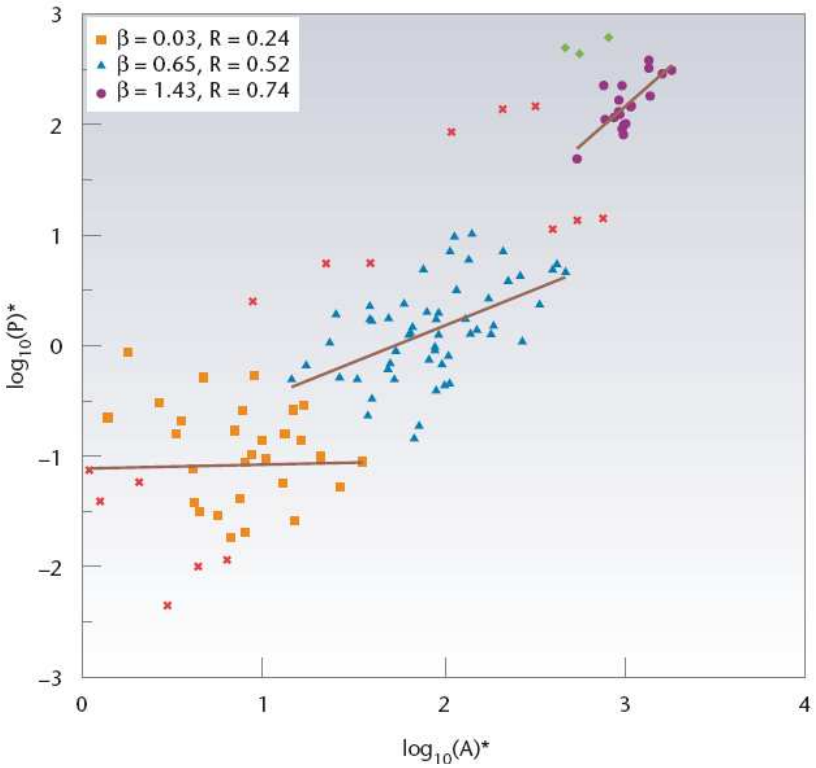


Source: Ribeiro, et al. (2006).

Figure 2.2 is a projection of the points on the A*-P* plane. We apply the super-paramagnetic clustering (SPC), method to analyze these points into significant subsets. Figure 2.2 shows three large groups, corresponding to three technological regimes. For each basic group we applied a linear fit to the dataset, thereby generating a power law between patents and scientific articles with exponent β. The first group (regime I) is formed by 29 countries. In these countries, the connections between the components of the NSI are very weak, as one can conclude from the low value β=0.03 (R^2=0.24). There are 54 countries in regime II, where β=0.65 (R^2=0.52). The highest value of β is 1.43 (R^2=0.74), observed in regime III, a small group of 19 countries. In this regime the NSI is fully formed and there is a higher rate of conversion from scientific production to innovation. There are 18 countries that do not belong to any of the three main clusters, 15 of them are represented by "x". The other three are Taiwan, Japan and United States, which are the represented by diamonds at the top of the plot. The same procedure was applied to the data for years 1974, 1982, 1990, and 1998. The SPC method again groups the data points into three clusters, with similar properties those observed in figure 2.2.

Figure 2.2

Three "regimes of interaction" between science and technology. The squares represent countries in regime I, triangles stand for those in regime II, and circles represent countries in regime III



Source: Ribeiro, et al (2006**).**

Figures 2.1 and 2.2 prepare Figure 2.3. Figure 2.2 defines three "regimes of interaction" and suggests the existence of thresholds between these three groups. Figure 2.3 shows that thes thresholds move – see the outward movement of these thresholds between 1974, 1982, 1990, 1998, 2003 e 2006.

These moving thresholds are important to suggest a very specific dynamic in that countries in "regimes" 1 and 2 seems to be subjected. After the identification of three "types" of NSI, Ribeiro et al (2006) evaluate the rate of movement of the boundaries between the associated technological regimes. The results show that over the period 1974-2003 the threshold between the immature and the developed NSIs (regime II and III) increased at an annual rate of 6.6% per capita. This means that in a decade, a country's scientific production must increase by 83% per capita, just to maintain its position in the global scheme. These steadily receding barriers to development in the world arena represent a kind of Red Queen Effect for societies in the throes of development.[15]

The relationship between level of development of the NSIs and the Red Queen Effect helps to identify the risk of falling behind and the challenges to staying ahead. The effort to avoid falling behind is a condition for a successful catch-up process, which demands to "run at least twice as fast

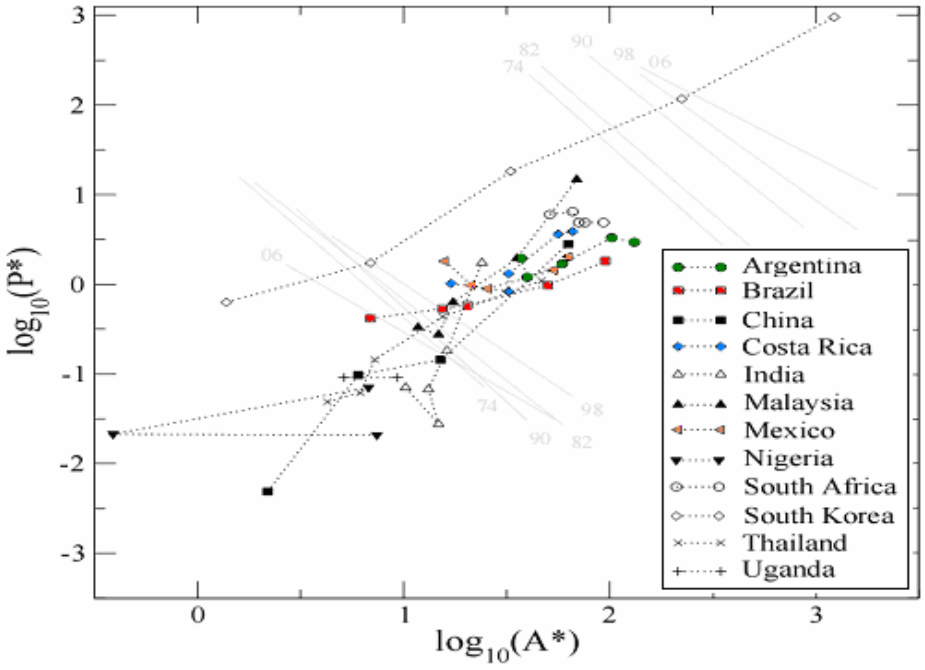
[15] van Valen, L. A New Evolutionary Law. *Evolutionary Theory* **1,** 1-30 (1973).

as that!" Large less-developed countries, such as South Africa and Brazil, would certainly require much additional effort to run faster. [16]

Figure 2.3 shows how complex is the periphery today, with its inner divisions (the periphery is divided between "regimes" I and II, and its differences in terms of trajectory (compare South Korea and the other 12 countries). Figure 2.3 locates very clearly South Africa and Brazil.

FIGURE 2.3

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.

[16] "Now, here, you see, it takes all the running you can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!". Caroll, L. . *Through the Looking Glass and what Alice found there*. Oxford/New York: Oxford University Press, p. 145 (1982).

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 2.3) and GDP per capita (see Figure 2.1).

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 2.1. Immature NSIs may characterize countries in Regimes I and II (Rapini et al, 2009). This characterization of South Africa and Brazil as immature NSIs is presented in a previous paper (see Albuquerque, 2003).[17]

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.

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

[17] The methodology suggested by Albuquerque (2003) was used later in a chapter for the *Handbook of quantitative science and technology research*: the use of publication and patent statistics in studies of S&T systems. (see Albuquerque, 2004).

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.

2.3 THE NATURE AND POSITION OF SOUTH AFRICAN AND BRAZILIAN TNCs

The potential role of home-based TNCs in the South African and Brazilian NSI thus deserves attention. The work of Ernst (2009) opens room for a subversion of pre-existing global hierarchies (Ernst and Hart, 2008 Ernst & Naughton, 2008), but the origin of the TNC is crucial. Cases related to Chinese and Taiwanese firms, TNCs in the making, are identified as possible actors for this key change. The home-base of types 3 and 4 of the tentative taxonomy is key for this process. The core sector of these TNCs depends on the strengths and specializations of each country's NSI. A list of top 100 non-financial developing and transition economies TNCs[18] shows the correlation between the developing countries largest TNCs and its home base scientific specialization. Brazil has three TNCs in this list (Vale, a mining company; Petrobrás, petroleum exploring and refining company; and Metalúrgica Gerdau, a steel producer). South Africa has eight companies, one in "wood and paper products", another in "metal and metal products", one in chemicals (Sasol)[19], four in "other consumer services" and one in "telecommunications".

This overall pattern from Brazil and South Africa may be compared with the pattern for Taiwan (with fourteen companies in the list, it has nine in the "electric and electronic sector") and Korea, (with five companies, it has two in the "electric and electronic sector"). China (13 firms and one in "electric and electronic sector", mixed with three petroleum companies and one "metal and metal products" firm) and India (with five firms, a petroleum firm, a metal producer and a car producer) also differ from both Brazil and South Africa and Korea and Taiwan.

Improvements in the size, diversity and quality of NSIs should impact on the process of formation of home-based TNCs in the periphery. In addition, the nature of those home-based TNCs may open space – through an active insertion in the international division of labor – for a less subordinate role in GINs and a more positive inclusion in global interactions between firms and universities. In short: the NSIs position within the international division of labor also determines the nature of the country's TNCs, which, in turn, shapes one important feature of the country's involvement in existing GINs.

2.4 NSIs, GINs AND THIS REPORT

That is why the theoretical framework presented in chapter 1, in particular the suggestion that both TNCs and the processes of NSI formation shape GINs, has one important implication for peripheral countries: the nature of NSIs shapes the national role in existing GINs. Therefore, immature NSIs will have immature (or incomplete) GINs. The limits of the NSIs will be reflected in the sectors and nature of these GINs. In particular, the nature and strength of interactions between firms,

[18] See http://www.unctad.org/sections/dite_dir/docs/wir2010_anxtab27.xls.

[19] At Sasol's site there is a statement that says: "we mine coal in South Africa and produce gas in Mozambique and oil in Gabon", an indication of the diversification of this TNC.

universities and research institutions should be an indicator of the level of maturity of a given GIN. This conjecture will be tested in relation to GINs in Brazil and South Africa.

The data and case studies prepared for the INGINEUS project help to identify the nature of the South African and Brazilian participation in existing GINs. As a corollary of these countries' position in the international division of labor, the role of foreign R&D is investigated in chapter 4. In other words, the analysis considers how South Africa and Brazil perform as host countries. The primary data source is a comparison of trends in national innovation surveys conducted in the two countries.

Chapter 6 will then go on to examine patterns of global interactions between firms and universities using the tentative framework and taxonomy. Research on the scale and nature of these different types of interactions is in its infancy, but a very simple initial scan identified instances of the involvement of South Africa and Brazil in at least six of the types. A few can be mentioned for illustrative purposes. Local firms and local universities have long established relationships – type 1 in our taxonomy (Kruss, 2009; Rapini et al 2009). For the historical roots of existing local interactions, see Pogue (2006) and Carvalho (2002). Embraer is an instance of type 3, a Brazilian TNC that developed from a deep relationship with one public institute (ITA, in São José dos Campos). We have identified instances of type 5, South African firms that have contacts with a local university that in turn has links with other local and foreign universities. Eucagen (International Eucalyptus Genome Network), a network that involves universities and firms (Fibria, Brazil), led by South Africa, Brazil and the United States (Penchel, 2008), or international networks of universities only such as the South-South network on tropical diseases (see http://www.ssi-tdr.net) could be at least rudimentary forms of type 7 global interactions.

Chapter 6 will focus specifically on the type 4 pattern of interaction - transnationals interacting both with home country and host country universities. Although both Brazil and South Africa are the home of TNCs, the focus will be on foreign TNCs operating in Brazil and South Africa. This focus is defined by the importance of foreign R&D in both countries, as will be illustrated in chapter 4.

Moreover, the literature on GINs has tended to focus on firms in the ICT sector (Ernst, 2006 and 2009). Two sectors not related to ICTs were thus selected as a focus, to allow for a closer investigation of the nature of such linkages in diverse sectors: agroprocessing and automotive. The two sectors have a long tradition of international production, and agroprocessing has a tradition of internationalization of R&D (Patel, 1995), and are thus likely to yield rich cases for investigation.

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CHAPTER 3: AN ANALYSIS OF THE INGINEUS SURVEY: INTERACTIONS, SECTORS AND COUNTRIES

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3.1 INTRODUCTION

This chapter investigates the existence of different profiles of companies and their interactions with local and foreign universities in eight countries researched by the INGINEUS Project. In those countries, data regarding the interaction between universities and companies, amongst other, were obtained, taking into consideration their national or global amplitude. These data come from a survey conducted by researchers from the INGINEUS project in South Africa, Germany, Brazil, China, Denmark, Estonia, Norway and Sweden. The project focused on three sectors of the economy: automotive, agro-processing and information and communication technology (ICT).

In the core of what this essay aims at, a set of variables is used to characterize the companies of the sample and their interactions with the university system. The statistic multivariate method of Multiple Correspondence Analysis has been used in order to read these data. Through this method, profiles containing elements of the sample and characterized by the chosen variables are identified. Thus, it was observed how the evaluated countries divided themselves amongst the distinctive profiles, defined according to the characteristics differing the companies of the sample and their interactions with the university system both in national and international scales.

In order to see to these purposes, the text has been divided into six sections. The second section presents the project INGINEUS and the methodologies of the survey and the Multiple Correspondence Analysis method. In the third section the results obtained with the multivariate method are summarized. The fourth section presents the concluding remarks.

3.2 THE INGINEUS PROJECT AND THE SURVEY[20]

The INGINEUS project focuses on the developed and developing world to determine the extent to which innovation is taking place in globally dispersed networks. This project aims to capture the dimensions of GINs (global, innovative and networked enterprises) through desktop research, a survey questionnaire and by means of appropriate cases which are examined and researched according to a pre designed set of parameters and constructs.

The survey was conducted across nine countries: Brazil, India, China, South Africa, Norway, Sweden, Germany, Estonia and Denmark. Each country had a dedicated sector of focus in either ICT, Automotive or Agro processing (Sweden had a small number of auto surveys in addition to ICT). Each institute conducting the survey across the nine countries chose a sector which was of economic importance within their national or regional context.

[20] This section is based on INGINEUS (2010)

The evidence also suggests that the outsourcing of knowledge-intensive activity and the emerging phenomenon of knowledge creation in developing locations outside the EU is spreading from the electronics sector to many other sectors of the economy, that is, from traditional low-tech industries such as agroprocessing or medium-tech such as automobile to high-tech such as ICT. A deeper examination of this phenomenon formed the motivation behind the sectoral choices of the ICT, Automotive and Agroprocessing sectors for this study. In order to adequately map this trend across the differing tech intensities of each sector the design ensured that each sector was covered by a more developed and less developed country as seen below:

- Agroprocessing: South Africa and Denmark
- Automotive: Brazil, Germany and a small sample from Sweden
- ICT: India, China, Sweden, Norway and Estonia

It is important to highlight that the observations related to India have not been included in the Multiple Correspondence Analysis due to problems experienced with the data compatibility. Then for this paper were used just eight of the countries surveyed by the INGINEUS project.

3.2.1 Survey Methodology

Because the central goal of the INGINEUS project was to track the globalisation of innovation networks, i.e. how global production networks were (or not) evolving into innovation networks, and what types of innovations were originating where, the project needed to adopt an inclusive rather than exclusive approach. However, for the sake of rigour, the research still needed to be clearly delimited.

Each country team conducting the survey also had to provide a list of the databases to be used, propose their sampling technique (random, stratified random) and sample criteria, e.g. minimum size of firm[21]. The sectoral definition per sample (ISIC/NACE codes) was also established.

Each survey country was required to set up an online survey tool through 'Survey Monkey'. In this way the survey progress could be monitored from a central site. The purpose of using a common survey tool which looked exactly the same across all survey countries was intended to assist with consistency across the project, streamline the research processes and to simplify the assimilation of the data at the end. All partners then cleaned and checked responses prior to downloading the data. The downloaded files were then mailed to WP 2 in a common Excel format for analysis. The WP 2 statisticians assimilated all the responses into a single spreadsheet. Following this a finalised dataset and codebook were assembled along with a set of reports and pivot tables based on the various levels of analysis. Table 3.1 shows the number of the survey responses for each country according to the sector.

Table 3.1: INGINEUS survey results by sector and by country

[21] It was decided that the minimum size of a firm for the survey would be five employees. There was no upper ceiling set for the size of the firm.

COUNTRIES	ICT	Auto	Agro
Brazil		69	
China	243		
Estonia	17		
Denmark			49
Germany		53	
Norway	181		
South Africa			84
Sweden	171	24	
Total sector	612	146	133
% total	**69%**	**16%**	**15%**

Source: INGINEUS Survey

The Swedish, South African, Norwegian, Danish and German surveys were national. Due to the size and geographical spread of the population in Brazil, China and India, these surveys were regional.

In Brazil the survey was thus confined to the region of Minas Gerais. The Brazilian automotive industry is however concentrated in the region of Minas Gerais therefore the majority of the relevant auto firms were represented in the databases. In India, cities with IT dense clusters were chosen as targets for the survey. These cities represented 93% of all the firms in the database. These cities included Bangalore, Delhi, Mumbai, Pune, Trivandrum, Hyderabad and Kochi. In China, face-to-face interviews or telephone interviews were found to offer the highest response rate. These challenges necessitated a regional approach therefore two regional databases were used, one focussing on Beijing and the other on Shenzen.

The survey was launched in Sweden, Norway and Denmark before October 2009 as these countries databases were updated and ready to use. It was launched in late January 2010 in Estonia, South Africa, China and Brazil as the database management was far more complex and demanded greater preparation.

The survey instrument consisted of 14 questions. Many of the questions had multiple sub questions. The questionnaire was structured to elicit information on firm behaviour around a clearly defined set of theories.

-**Question one** asked the respondent to briefly describe the enterprise's main product (goods or services).

-**Question two to four** elicited background information about firm size, market, sales information and R&D activity.

-**Question 5 and 6** were innovation based questions.

-**Questions 7 and 8** probed the firms geographic network and collaborations with customers, suppliers, Universities, research institutions, government etc.

-**Question 9 and 10** were detailed questions around offshoring and regional attractiveness.

-Questions 11, 12 and 13 were policy based questions

-Question 14 examined the impact of the global economic crisis on innovative activity.

3.2.2 Multiple Correspondence Analysis Method

The Multiple Correspondence Analysis (MCA) is a multivariate statistical method that allows to verify the association between more than two categorical variables. This technique aims mainly at transforming qualitative information available in a table in an instrumental chart, in order to make the analysis of data easier (GRENACRE, 1994). The display of categories related to observed variables on a Correspondence Graph allows us to evaluate its association to determine into which profiles the observations comprised in the sample can be divided.

The analysis of these observations, described by a set of variables and their categories, will occur by reducing the dimensionality of the system so that information can be systematized in a plane (GRENACRE, 1994). It is known that the graphical analysis of the association of variables is done through the representation in the space of dimensions that reflect their behavior. The number of dimensions evaluated increases as it increases the number of variables observed. This makes the association of a large set of variables infeasible to be observed. The Multiple Correspondence Analysis serves to reduce the dimensions required for graphic display of a set of variables, eliminating such limitation. Thus, the method generates a smaller number of dimensions (usually two) that summarize the information present in the set of variables observed.

The method starts from an indicative array, whose number of rows equals the number of observations, whereas its number of columns equals the sum of the number of categories of all variables observed. This array's values equal to 0, which indicates that the individual does not belong to a particular category, to some specific variable; and 1, which indicates the opposite. That being said, each row of the indicative matrix consists of a sequence of values 0 and 1, according to the characteristics of the individual it represents.

Based on these data, main coordinates (referring to rows and columns from the matrix that data come from) are calculated to each one of the categories of the evaluated variables. These coordinates will be the product of linear combinations of the original variables. These combinations are responsible for generating data present in the set of variables in a smaller number of dimensions.

The criterion for comparison between any two categories, j and k, for the set of variables observed, is given by the chi-square distance, defined by $d2_{\mathbf{j,k}} = n[(n_{\mathbf{j}} - n_{\mathbf{j,k}} / n_{\mathbf{j,k}}) + (n_{\mathbf{k}} - n_{\mathbf{j,k}} / n_{\mathbf{j}}n_{\mathbf{k}})]$, being $n_{\mathbf{j,k}}$ a raw frequency of those individuals that have both categories **j** e **k**. The term $n_{\mathbf{j}}$ represents the raw frequency of individuals that have only the category **j** and $n_{\mathbf{k}}$ the raw frequency of individuals that have the category **k**.

In possession of this set of information, the coordinates of each category are plotted on a correspondence chart, as to the new dimensions created for analysis. The association between different categories of the variables observed is defined by chi-square distance between them. In this context, the proximity of the analyzed categories in the correspondence chart will determine the association between them. This association is used as the basis for the identification of profiles containing the elements of the sample. Therefore, the common relationship between the categories of the original variables in comparison to the dimensions obtained by the MCA will set the tone of

the association of categories forming distinct profiles in which elements of the sample can be classified.

The exercise of the Multiple Correspondence Analysis used in this article was based on data drawn from the results of the survey conducted by the INGINEUS project, given 891 observations, referring to the eight countries that joined the research and the three sectors of economy. Each country of the sample is associated with a specific sector, as mentioned above, except for Sweden that presents observations for the automotive and ICT sectors. That is why Sweden will be discriminated in the following analysis according to these sectors (Sweden Auto and Sweden ICT). From the survey, nine variables used in the analysis were obtained. Questions used in the survey and the variables derived from them, their codes and categories for each of them, are represented in attachment 1 of this essay.

3.3 MULTIPLE CORRESPONDENCE ANALYSIS EXERCISE RESULTS

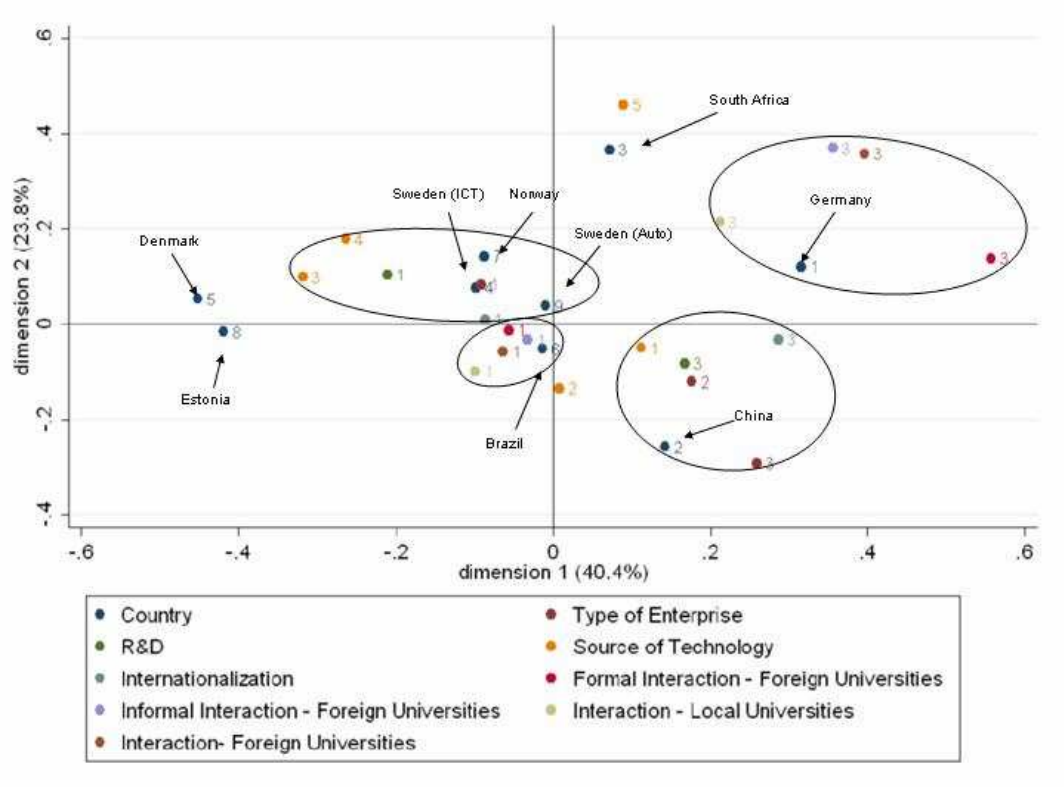
3.3.1 Analysis Featuring the Eight Sample Countries

Represented below is the correspondence chart obtained for the analysis of the eight countries that have been selected. Each one of the chart axes represents a new dimension that summarizes the information of the set of variables, enabling its display in a simple two dimensional plane, which is this case[22].

The disposition of categories in Chart 3.1 allows us to define four different profiles, those being distributed in the chart's quadrants. These profiles can be identified and interpreted according to the variable 'country'. One profile may be classified by Germany's presence, one by China's, one by Sweden's and Norway's and one by Brazil's can be found.

[22] The characterization of variables used in this exercise can be found in Attachment 1.

CHART 3.1: Multiple Correspondence Analysis for ICT, Agro-processing and Automotive sectors according to INGINEUS *Survey* data



Source: INGINEUS *Survey*. Authors' elaboration.

The first profile observed is identified by the presence of Germany. It is possible to identify some characteristics that are expected to more advanced innovation systems. It can be observed that the variables that indicate the existence of interactions between universities and companies are arranged in a track farther to the right in the first quadrant of the matching chart, featuring the German profile. Because of this, we can say that its most striking feature is the relevance of interactions between universities / research institutes and companies, and these include both local and foreign universities[23]. The presence of Germany in this profile is fully justified since, according to the evidence from the survey conducted by the INGINEUS project, from the eight countries evaluated in the MCA procedures, this is the one with the highest proportions of participants who reported having some type of interaction with universities and local research institutes, also showing good indicators for the interaction with foreign institutions. The arrangement of variables in that region of the first quadrant can therefore define it as a profile of interaction between universities /research institutes and companies.

[23] When characterizing this profile, it is possible to notice that the variable 'Formal interaction with foreign universities' can be a found a little further that the other shaping it. That is why, it is possible to say that this variable contributes less in determining it, as a stricter analysis in shaping the groups would cut it off this profile. Given this variable is strongly related to the ones that characterize the profile, we have opted for a more flexible criterion in shaping it.

Still in the first quadrant, it is possible to identify the presence of South Africa, positioned, however in a more diffused manner than the other variables, what leads saying this economy has a peculiar profile. The only variable that presents a strong association with South Africa is the one that indicates universities and research institutes as main sources of technology to the companies. This association also shows a tendency to interaction when it comes to South Africa. Nevertheless, South Africa's diffused position in the quadrant confirms the existence of a distance between this country and Germany according to the characteristics of the elements of the sample[24]. Which leads us to believe that the German profile is marked by interactivity between universities / research institutes and companies. Whereas the South African can be defined by a certain dependence regarding the developments of the university.

In the second quadrant of the correspondence chart, the characterization of the profile marked by the presence of China shows a tendency to the existence of large companies of international scope. This is explained by variables that indicate the existence of significant R&D, the inner search for technology and presence firms that have done some kind of internationalization of R&D or production processes. Those characteristics are usually related to companies of a larger scale. The variable "type of company" has two categories in this profile, indicating that it is characterized by the presence of multinational corporations, whether subsidiaries or headquarters. In the survey, China has a prominent position in this regard, as it is the country that shows the largest number of multinational companies for the two categories, besides being the largest number of companies participating in the survey.

In the third quadrant of the correspondence chart it is possible to notice a profile formed by the Nordic countries, among which Norway and Sweden and featuring the two sectors surveyed in the latter. It is observed then a strong association between the two countries, considering the ICT sector, as these are very close in the chart[25]. Moreover, the automotive industry in Sweden (Sweden Auto) appears slightly detached in comparison to ICT. It appears, then, that even if it stands in the same profile there is some differentiation between ICT participants in Sweden and Norway and the automotive sector participants in Sweden, perceived in their proximity in the third quadrant. It can also be noticed that the profile shows a significant presence of independent companies (not subsidiaries or headquarters of multinationals), that is, smaller-scale enterprises. Another of their characteristics are the absence of R&D and the purchase of knowledge from other companies - MNC's or not - standing as main source of technology for the company.

Brazil figures in a profile that is characterized by the absence of formal or informal interactions with local or foreign universities. This is a profile that opposes to the one characterized by the presence of Germany, which is more interactive. Brazil is one of the countries polled in the survey that showed a lower proportion of positive responses to the variables indicating interaction between universities and research institutes both domestically and abroad, which helps to understand the country's position in this profile. Therefore, one can set this profile as the trend marked by the absence of interactive activities.

Estonia is quite widespread in the fourth quarter showing still strong proximity to the horizontal axis, which indicates the tendency for a lack of association with the variables in the analysis. The

[24] It is valid to mention then that it is one of the countries with the largest number of participants who have stated maintaining interactions with universities.

[25] It is important to remember that Sweden has two sectors represented in the database (ICT and automotive), and they are both discriminated in the analysis (Sweden ICT and Sweden Auto).

same goes for Denmark in the third quadrant. That is why, it is possible to think of those countries as scattered in the present analysis.

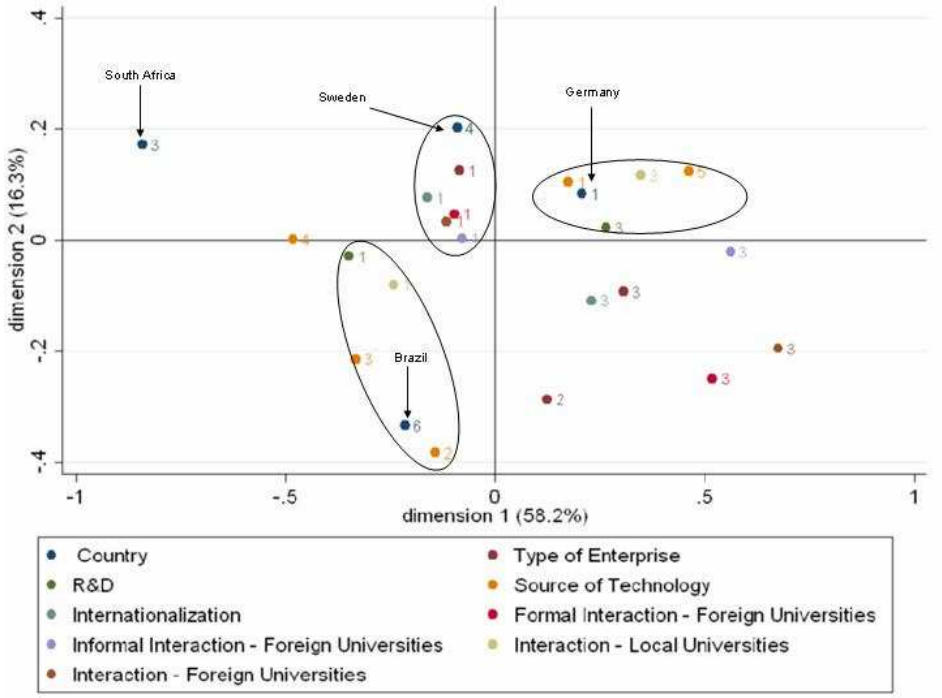
In the following subsections the exercise of MCA above was replicated for each of the sectors that comprise the survey sample, considering the countries associated with them.

3.3.2 Multiple Correspondence Analysis for the Automotive Sector

The exercise of Multiple Correspondence Analysis was replicated considering only the portion of the sample featuring participants of the automotive sector. The number of countries evaluated in this procedure is then reduced compared to the previous one, comprising Brazil, Sweden, Germany and South Africa. The sample for this exercise consisted of 149 observations.

Through the correspondence chart, shown below, one can see a certain distribution of the assessed countries in the plane, according to the variable 'country'. The category of the variable 'country' indicates that South Africa stands quite loose in the correspondence chart, which indicates its lack of association with the set of analysed variables. This may be due to low numbers of answers to the survey in the automotive industry in this country. On the other hand, the categories of the variable 'country' that indicate the other assessed countries are clearly divided in quadrants of correspondence chart, generating profiles shaped by variables associated with them. Therefore, it is possible to glimpse in the first quadrant a profile marked by the presence of Germany; in the third one, a profile marked by the presence of Sweden; and in the forth one, a profile marked by the presence of Brazil. The third quadrant of the correspondence chart shows the association of a set of variables regardless of the variable 'country', i.e. not associated specifically with any of the countries assessed.

CHART 3.2: Multiple Correspondence Analysis for the Automotive Sector according to the INGINEUS *Survey* data



Source: INGINEUS *Survey*. Authors' elaboration.

The first profile that can be assessed, whose main characteristic is the association with Germany provides the categories of the variables that indicate characteristics of a more advanced system of innovation, as well as in the previous exercise. These categories are the existence of significant R&D and interaction with universities and local research institutes. These results of ACM can be confirmed by the analysis of the responses to the survey. These evidences are also corroborated by the variable "main source of technology" which has two categories composing this profile, indicating the universities and research institutes as the main sources of knowledge as well as the company itself.

The second profile identified by the presence of Sweden is characterized by the presence of the variable that indicates the occurrence of autonomous companies (not MNCs headquarters nor subsidiaries). The lack of internationalization of R&D activities and production, identified by the negative category of the variable 'Internationalization' helps to characterize this profile as being related to companies of a smaller scale and a small international range. The variables related to interaction with universities and research institutes show a tendency towards its non-existence, taking into consideration the institutions of other countries. Based on the characteristics of this profile, it is possible to say that it would refer to companies of a smaller scale with no international scope that have not established foreign connections in their technological processes.

The third profile observable through this exercise is the one identified by the presence of Brazil. Characterized by knowledge purchased from other branches of the MNC and non-MNCs. In this profile it is possible to observe two features relating to less developed innovation systems. Those are: not performing significant activities of R&D and the indication of the absence of interactions with universities and local research institutes. This profile is still characterized by the variable "Main source of technology", which indicate the purchase of technology from other MNC branches and other non-MNC companies. This quadrant thus associates Brazil to a profile of dependence on technology purchases, with low internal efforts aimed at innovation and low inclination to interact with universities and research institutes.

As previously mentioned, there is yet a profile that is not associated with any specific country, in which it is possible to identify the positive categories for formal and informal interaction with universities and research institutes abroad and internationalization of R&D activities and production. It is also observed in the quadrant that defines this profile the categories that indicate the type of company as headquarters and subsidiary of MNCs. The presence of these categories classifies this profile by the presence of global companies that have formal and informal relationships outside the country where they act, that have performed processes of internationalization of their R&D activities and production and work on a large scale. It is clear that the variable 'country' is not an important variable to differentiate this profile of the others that have been obtained, as it does not integrate it into any of their categories.

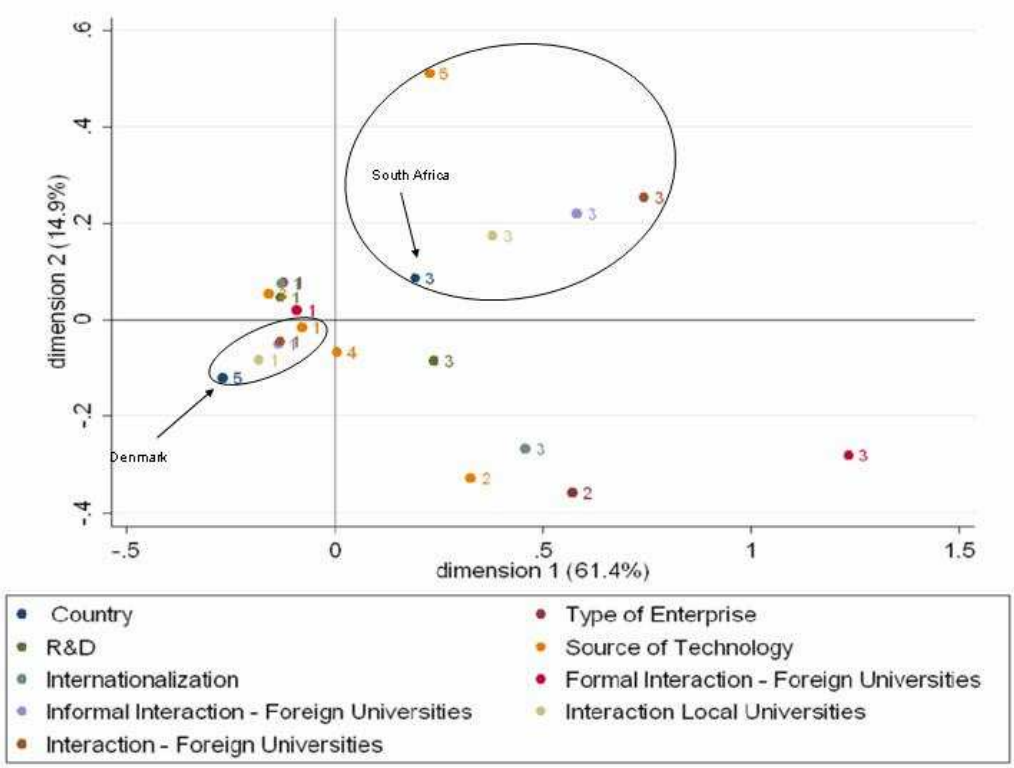
3.3.3 Analysis for the Agroprocessing Sector

The Multiple Correspondence Analysis exercise embodying only observations related to the agro-processing sector displays distinct patterns for both countries that have observations in this sector, South Africa and Denmark. Moreover, the correspondence chart shows two other profiles that are not associated with any of those countries specifically.

It is possible to observe South Africa associated with a profile marked by the variables of interaction taken into account in this analysis. It is about a profile that shows the existence of interaction between companies and local and foreign universities - mainly informally with the latter. In this profile, universities and research institutes are indicated as main sources of technology to the companies.

As for Denmark, it is found a less likely to interact profile. The variables that indicate interaction present its absence for this profile, whether when it comes to local or foreign universities. In this profile it is possible to observe the company as its own main source of technology, what corroborates with the lack of interaction opposed to the South African profile.

CHART 3.3: Multiple Correspondence Analysis for the Agro-processing Sector according to the INGINEUS *Survey* data.



Source: INGINEUS *Survey*. Authors' elaboration.

It is also possible to verify the existence of two other profiles that are not aligned to any of the two specific countries, but to the type of company. In the second quadrant it is possible to observe that the variable that displays the autonomous companies (not headquarters nor subsidiaries of MNCs) is associated with the variables indicating the non internationalization of the company's activity and the absence of R&D. This profile is also characterized by the absence of formal interactions with universities and foreign research institutes. In this profile the main source of technology is the purchasing of other non MNCs companies.

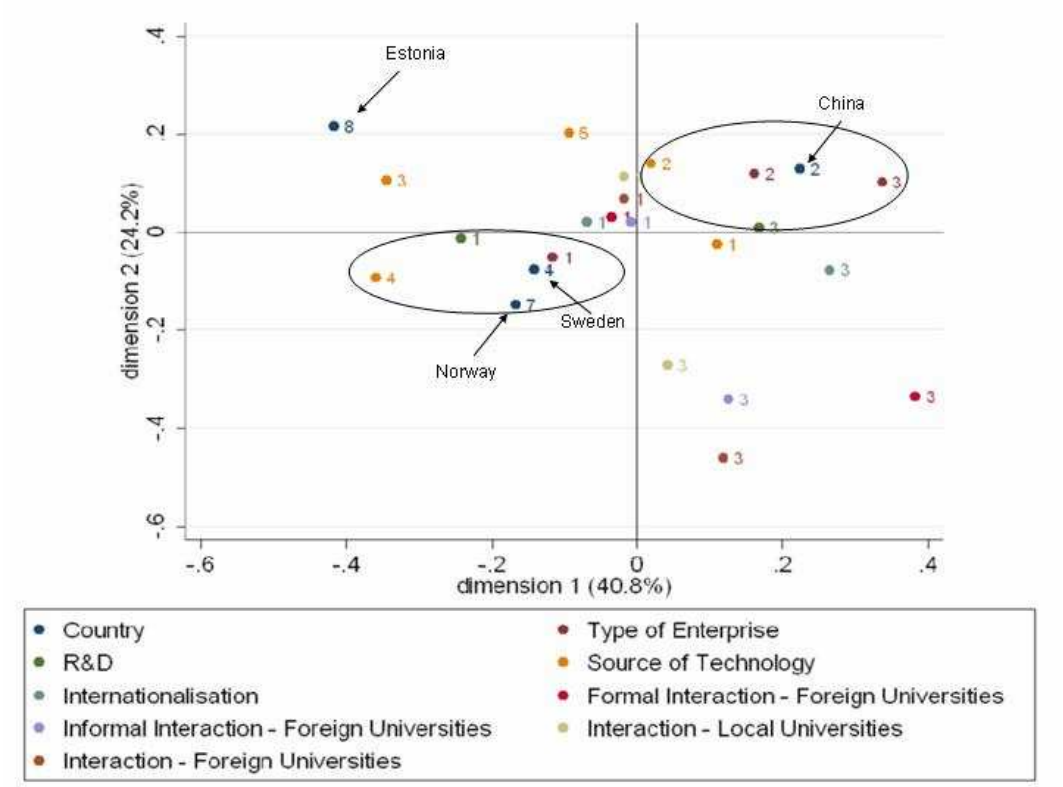
As for the profile displayed in the forth quadrant, it is marked by the presence of subsidiaries and multinationals. It is possible to observe in this category the association of variables that indicate the

significant existence of R&D activities and of internationalization of R&D activities and the company group's production. It is also possible to observe the indication of formal interactions with universities and foreign research institutes, although the variable associated to this evidence is shown scattered from the rest of them. The variable 'Main Source of Technology for the Company' shows that the tendency of the companies associated to this profile is to seek for technology in other branches of the MNC with which they are associated.

3.3.4 Analysis for the Information and Communication Technology Sector

The analysis for the ICT sector also shows the discrimination of the observed countries in distinct profiles displayed in the correspondence chart. The first quadrant is characterized by the presence of China. In this profile, China is associated with the existence of multinational companies - headquarters and subsidiaries- and the ones that do R&D. Those characteristics were also found in the China's profile in the first MCA exercise with all the components of the sample. The variable 'Technology Source' indicates that the main channel associated with this quadrant is the acquisition along with other branches of the MNC.

CHART 3.4: Multiple Correspondence Analysis for the ICT Sector, according to the INGINEUS *Survey* data.



Source: INGINEUS *Survey*. Authors' elaboration.

Sweden and Norway are shown in another profile, characterized by the existence of autonomous companies (non-MNCs). This profile also shows the absence of R&D activities by the companies and a tendency to purchase technologies from MNCs, with which the companies are not

formally linked. These results follow the same pattern as the ones observed in the general analysis for all sectors of the sample. As for Sweden, there is a similarity to the result obtained for the exercise that embodied only the automotive sector.

A third profile that can be verified in the correspondence chart shows Estonia associated with the search for technology in non MNCs companies and in universities and other public institutes. In this profile the absence of internationalization of the production and R&D activities are noticed. In this profile, the absence of interactions between companies and universities whether local or foreign is also a characteristic.

Finally, it is possible to verify a forth profile that is not associated with any of the assessed countries. Its main characteristic is the presence of variables of interaction between university and company, both local and foreign. It is also observed that in this profile the main source of technology for the firms comes from within, given that they also display processes of internationalization of their production and R&D activities.

3.4 CONCLUDING REMARKS

This paper aims at identifying the existence of patterns of university-company interaction, according to the different countries and sectors of the sample obtained from the survey performed by the INGINEUS project. Using the multiple correspondence method it has shown that the observations of the sample can really be categorized in distinct profiles, each of the generally associated with a specific country or region. The behaviour of the variables that have been used allows the identification of specific characteristics for each one of the countries analyzed, which leads to the differentiation. As a result, it is evident that the dichotomy centre-periphery is maintained as a characteristic of these profiles and an internationalization of the crucial productive activities for the industry toward China.

Germany, when it comes to the university-company interaction, has shown results agreeing with what had been expected for more advanced innovation systems, whereas South Africa and mainly Brazil have shown some deficit in this matter. The European country stands as the one with the highest tendency of interaction opposed to the other two that do not associate with the variables that indicate the companies relationship with the university system, whether on the inside or the outside. As for the automotive sector specifically, this dichotomy is very noticeable. Germany is opposed to Brazil as it displays a strong tendency to the university-company interaction, whereas the latter depends on technology developed abroad.

The centre-periphery dichotomy is not evident only for the agro-processing sector. Amongst the countries that have displayed observations in this sector it is possible to observe that South Africa has a strong tendency to interact, opposite to Denmark. Notwithstanding, this result needs to be considered in the light of the relative importance of this sector in both countries, distinct as it is.

As for China, it can be characterized as an exception. The internationalization of the multinational companies' most important activities, regarding production and R&D, stands as a characteristic mostly related to China. That indicates a rising importance of this economy internationally speaking. Even though the Chinese economy has not displayed characteristics connected to the university-company interaction, the profile in which it stands is also characterized by the existence of R&D within the companies. This makes of China a new field for the internationalization not only of the MCNs production but also of its research and development. The specific analysis for the

ICT sector shows that China assembles large multinational companies, working in an international scale.

Finally, the analysis developed in this essay all point to the fact that the characteristics connected to the university-company interaction generates patterns strongly aligned to the centre-periphery dichotomy. As China is seen as a rising economy in a global context for being strongly associated with the large multinational corporations production activities expansion. However, when it comes to the interactions between companies and universities both local and foreign, characteristics regarding the GINs are associated with Germany, which display the most advanced innovation system amongst the ones assessed.

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ATTACHMENT 1: Summary of the Data used in the Multiple Correspondence Analysis

Question	Varible	Code	Options
	Country	Country	1. Germany 5. Denmark 2. China 6. Brazil 3. South Africa 7. Norway 4. Sweden 8. Estonia 9. Sweden-Auto
3.3 Do you have significant R&D activity?	R&D	R_D	1.No 3. Yes
9.1 Regarding internationalisation, does your firm offshore (or has your firm offshored) production or any R&D activities?	Internationalization	Internation,	1.No 3. Yes
8. Has your enterprise developed formal/informal linkages (e.g. research relationships) with the following kinds of foreign organisations?	Informal Interaction with Foreign Universities and Research Centers	Inter_inf_for	1.No 3. Yes
	Formal Interaction with Foreign Universities and Research Centers	Inter_formal_for	1.No 3. Yes
7. Regarding the development of the most important innovation of your firm in the last 3 years: who did you actively collaborate with and in which geographical location?	Interaction with Local Universities and Research Centers	Inter_local	1. No 2. Yes
	Interaction with Foreign Universities and Research Centers	Inter_foreign	1. No 2. Yes
2. Are You?	Type of Enterprise	Enter_type	1. A standalone Company 2. A subsidiary of a MNC 3. The Headquarters of a MNC
5. Which is the most important source of technology for your enterprise?	Main source of Technology.	Know_source	1. We produce most technological inputs in-house 2. We buy most of our inputs from other branches of our own MNC 3. We buy most of our technological inputs from non-MNC firms 4. We buy most of our inputs from MNCs with which we are not formally connected 5. We buy most of our inputs from public-sector organizations, e.g. research institutes, universities etc.

Source: INGINEUS Project.

CHAPTER 4: INNOVATION SURVEYS AND THE SPECIFICITIES OF LOCAL AND FOREIGN FIRMS

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4.1 INTRODUCTION

This chapter analyses the South African and the Brazilian Innovation Surveys focusing in the information that assesses the differentiation between local and foreign firms. This differentiation is investigated also in regard to the nature of cooperation established by both sets of firms in general and with universities and public research institutes.

In addition, this chapter introduces data that help to locate the South African agro-food industry and the Brazilian auto-industry in the national technological dimensions, information that is important for the next chapter (case studies).

This chapter first discusses the South African data (section 4.2), then presents the Brazilian data (section 4.3) and finally summarizes key information on both countries.

4.2 SOUTH AFRICA: SAIS (2005), DOMESTIC AND FOREIGN FIRMS

This paper presents selected innovation indicators from the South African Innovation Survey, conducted in 2005. The analysis focuses on the innovative activities and collaborative partners of domestic and foreign firms, across all South African firms in section 4.2.1, and in relation to agro-food processing firms specifically, in section 4.2.2.

4.2.1 Innovative Activities of Domestic and Foreign Firms in South Africa

A total of 2 627 enterprises were interviewed for the Innovation Survey 2005. The results of the survey were extrapolated to the target business population of 31 456 enterprises based on the weights of 120 strata (Blankley and Moses, 2005).

About 51.7% of the enterprises in the survey indicated that they were involved in innovation activities between 2002 and 2004. Of these innovative firms, 91% were domestic and only 9% were foreign owned firms/had their head offices in foreign countries. However, 80% of foreign firms were innovative, in contrast with 50% of the domestic firms.

Table 4.1: **Number of Innovative and non-innovative firms.**

	Domestic	Foreign	Total
Innovative	**14 876**	**1 388**	**16 264**
Non-innovative	**14 864**	**328**	**15 192**
Total	**29 740**	**1 716**	**31 456**

Source: SAIS (2005)

Total turnover of firms in the survey is estimated to be R1 144.4 billion rands. Domestic firms (both innovative and non-innovative) accounted for 71% of the total turnover while foreign firms accounted for 29%. A break-down of turnover reveals that domestic innovative firms alone contributed about 49.3% of the total turnover whereas foreign innovative firms accounted for 26.2%, domestic non-innovative firms 22.3% and foreign non-innovative firms contributed 2.2%.

Table 4.2: **Turnover of firms (R Million)**

	Domestic	Foreign	Total
Non-innovative	R256 042	R24 770	R280 812
Innovative	R564 043	R299 589	R863 632
Total	R820 085	R324 359	R1 144 445

Source: SAIS (2005)

The innovative firms spent approximately R27.8 billion on activities related to innovation. These represent about 3.2% of the innovative enterprises' turnover. Innovation expenditure is divided into four categories, namely, Internal R&D, External R&D, Acquisition of machinery and Acquisition of knowledge. Domestic firms are by far the biggest spenders on R&D activities compared to the foreign firms. Domestic firms accounted for 77.7% of the innovative firms' expenditure on R&D in 2004.

Table 4.3: **Firm expenditure on innovation activities (R Million)**

	Internal	External	Machinery	Knowledge	Total
Domestic	R4 780	R1 710	R13 807	R1 268	R21 565
Foreign	R911	R480	R4 277	R573	R6 241
Total	R5 691	R2 190	R18 084	R1 841	R27 806

Source: SAIS (2005)

Table 4.4 below provides an overview of innovation expenditure by sector. The manufacturing sector is the largest spender on innovation activities with over R11 billion of expenditure. The domestic manufacturing sector alone contributed over R7 billion towards the total innovation expenditure by the manufacturing sector. The domestic manufacturing sector spent about R5 billion on acquisition of machinery, compared to R2 billion spent by foreign firms.

However both domestic and foreign firms spent more on acquisition of machinery than any other innovation activity. Domestic firms alone spent over R13 billion on acquisition of machinery compared to R4 billion spent by foreign firms. Domestic firms generally spent more than their counterpart firms across different innovation activities and sectors.

Table 4.4: **Innovation expenditure by sector (R Million)**

	Domestic firms				Foreign firms				
	Internal	External	Machinery	Knowledge	Internal	External	Machinery	Knowledge	Total
Mining	R670	R150	R506	R51	R14	R2	R73	R0.757	R1 467
Manufacturing	R1 967	R459	R5 348	R81	R490	R113	R2 585	R90	R11 133
Electricity, Gas etc	R13	R0.949	R10	R1	R0.276	R0.276	R3	R0.138	R29
Wholesale and retail trade	R1 046	R451	R1 465	R402	R144	R193	R565	R200	R4 466
Transport and communication	R252	R11	R4 222	R47	R57	R0.353	R30	R0.480	R4 620
Financial intermediation	R30	R3	R4	R64	0	0	0	0	R101
Services	R274	R146	R355	R115	R205	R171	R1 000	R273	R2 539
Other business activities	R529	R489	R1 897	R507	0	0	R21	R9	R3 452
Total	R4 780	R1 710	R13 807	R1 268	R911	R480	R4 277	R573	R27 806

Source: SAIS (2005)

A total of 13,081 innovative firms identified themselves as product innovators. Of these firms, 12,031 were domestic and 1,050 were foreign owned. On the other hand, a total of 11 133 firms identified themselves as process innovators, of which 9 976 were domestic and 1 157 were foreign owned.

Table 4.5: **Innovation activities**

	Product innovation	Process innovation
Domestic	12 031	9 976
Foreign	1 050	1 157
Total	13 081	11 133

Source: SAIS (2005)

About 36.8% of the domestic innovative firms (product innovators) introduced products that were new to the market whereas 50.7% of the foreign firms introduced products that were new to the market. About 58.8% of the domestic firms introduced products that were new to their firm as compared to 80.8% of the foreign firms that introduced products that were new to their firm.

Table 4.6: **Novelty of product innovation.**

	New to your market	New to your firm
Domestic	4 438 (36.8%)	7 075 (58.8%)
Foreign	533 (50.7%)	848 (80.8%)

Source: SAIS (2005)

About 36.8% (4 417 of 14 876) domestic innovative firms indicated that they cooperated with other institutions or enterprises between 2002 and 2004, while 50.7% (597 of 1 388) foreign innovative firms indicated cooperation with other institutions. The SAIS defined innovation co-operation as "active participation with other enterprises or non-commercial institutions on innovation activities. Both partners need to benefit commercially".

Table 4.7: **Cooperation with other institutions**[1]

	Total	Percentage of innovative firms
Domestic	4 417	36.8%
Foreign	597	50.7%

Source: SAIS (2005)

Table 4.8 below shows the type of co-operation partner that firms engage with and their location. Looking at the location of the partner, a majority of the firms indicated that their partners are in South Africa. The numbers in brackets express the total number of firms that responded "yes" to the type of partner and location questions as a percentage of domestic innovative firms. About 16% of the firms interviewed indicated involvement with universities in South Africa and this figure declines to less than 1% across all foreign locations.

Table 4.8: **Type of co-operation by partner and location: Domestic firms**

	South Africa	Rest of Africa	Europe	USA	Asia	Other countries
Enterprises in same group	3 460(23%)	1 95(1.3%)	437 (2.9%)	192(1.3%)	141(0.95%)	88(0.59%)
Suppliers of equipment etc	4 353(29%)	1 04(0.7%)	1 248(8.4%)	518(3.5%)	47(0.32%)	419(2.82%)
Clients/customers	5 513(37%)	279(1.9%)	271(1.8%)	153(1.0%)	128(0.86%)	144(0.97%)
Competitors	4 284(29%)	77(0.5%)	379(2.5%)	338(2.3%)	92(0.62%)	18(0.12%)
Consultants	2 453(16%)	11(0.1%)	129(0.9%)	72(0.5%)	23(0.15%)	39(0.26%)
Universities etc	2 433(16%)	0(0%)	84(0.6%)	58(0.4%)	2(0.01%)	26(0.17%)
Research institutes	2 092(14%)	13(0.1%)	63(0.4%)	51(0.3%)	2(0.01%)	26(0.17%)

Source: SAIS (2005)

Foreign owned firms also have a majority of their innovative partners in South Africa. About 5% of the firms indicated South African universities as their innovative partners. Cooperation between foreign owned firms and universities also declines (similar to the domestic industries). About 0.6% of firms indicated that they cooperated with European universities, 0.5% cooperated with South African universities, 0.1% of other African universities, 0.1% universities in other countries and they did not co-operate with any of the universities in USA and Asia.

Table 4.9: **Type of co-operation by partner and location: Foreign firms**

	South Africa	Rest of Africa	Europe	USA	Asia	Other countries
Enterprises in same group	424(31%)	14(1.0%)	556(40.1%)	493(35.5%)	21(1.5%)	23(1.7%)
Suppliers equipment,etc	470(34%)	3(0.2%)	148(10.7%)	23(1.7%)	17(12%)	28(2.0%)
Clients/customers	480(35%)	397(28.6%)	52(3.7%)	23(1.7%)	17(1.2%)	23(1.7%)
Competitors	450(32%)	15(1.1%)	27(1.9%)	16(1.2%)	386(27.8%)	24(1.7%)
Consultants	458(33%)	0(0%)	30(2.2%)	12(0.9%)	9(0.6%)	6(0.4%)
Universities etc	72(5%)	2(0.1%)	9(0.6%)	0(0%)	0(0%)	2(0.1%)
Research institutes	56(4%)	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)

Source: SAIS (2005)

A comparison of domestic and foreign innovative firms' co-operation activities with different partners reveal that they are more likely to co-operate with partners in South Africa than anywhere in the world. This is also true for universities as co-operative partners, where domestic firms tend to co-operate more with South African universities than their foreign-owned counterparts.

Table 4.10 below shows the sources of information for innovation activities, as rated by the firms in the survey. The numbers presented shows the total number of firms that rated the importance of particular sources of information. About 25% (7 614) of domestic firms rated enterprises within same group as "highly" important source of information compared to 23% (407 of 1 716) of foreign firms. Of interest in this table is the rating of universities/technikons and scientific publications. About 2% of the domestic firms rated scientific publication as highly important source of information compared to 1% of the foreign firms. On the other hand about 3% of the domestic firms rated universities as highly important sources of information as compared to 0.11% of the foreign firms.

Table 4.10: **Importance of sources of information**

	Domestic			Foreign		
	Low	Medium	High	Low	Medium	High
Enterprise within group	937	2832	7614	209	506	407
Suppliers	3151	4144	3337	217	513	615
Competition	3320	3606	646	207	7149	79
Clients	3499	4199	5000	164	R 323	613
Consultants	915	2994	620	719	118	14
Universities	925	2702	851	171	41	2
Research institutes	908	225	543	75	127	2
Conferences	1845	6502	321	235	762	42
Scientific publication	3746	3998	598	167	718	22
Industry associations	1767	3652	1375	216	577	29

Source: SAIS (2005)

In general, foreign firms are more innovative and are more likely to cooperate with other partners on their innovative activities, but domestic firms are more likely to cooperate with local universities.

4.2.2 Innovation in the agrofood processing sector (Manufacturing of food etc)

This section presents only the results of those firms involved in manufacturing and processing of food. A total of 1,628 domestic and 10 foreign agrofood processing firms are included in the Innovation Survey.

A breakdown into innovative and non-innovative firms shows that there are about 434 domestic innovative firms (27%), which is less than the national average of 50% of domestic firms. All 10 foreign firms are innovative.

Table 4.11: **Innovative and non-innovative agrofood processing firms**

	Innovative	Non-innovative	Total
Domestic	434	1 194	1 628
Foreign	10	0	10

Source: SAIS (2005)

About 30% of the domestic innovative firms reported to be part of a larger group whereas all of the foreign firms were part of a larger group.

Table 4.12: **Part of the large group**

	Yes	No
Domestic	129 (30%)	305(70%)
Foreign	10 (100%)	0

Source: SAIS (2005)

The agrofood processing sector turnover was about R41 billion in 2004. This represents about 4.1% of the total turnover of the firms in the survey. Innovative agrofood processing firms alone contributed over 3.05% towards the total turnover while non-innovative agrofood processing firms contributed about 3.6%. The total turnover of both domestic and foreign agrofood processing firms is presented in Table 4.13 below.

Table 4.13: **Turnover of firms in the agroprocessing (R Millions)**

	Domestic	Foreign	Total
Non-innovative	R12 227	R0	R12 227
Innovative	R29 668	R5 298	R34 966
Total	R41 895	R5 298	R47 193

Source: SAIS (2005)

Agrofood processing firms spent about 1% of their turnover on innovation activities. About R 410 million was spent on internal R&D, external R&D, acquisition of machinery and acquisition of knowledge.

Table 4.14: **Agroprocessing expenditure on R&D (R Millions)**

	Internal	External	Machine	Knowledge	Total
Domestic	R 105	R 4	R 246	R 22	R 377
Foreign	R 16	R 0.41	R 16	R 0.31	R 32
Total	R 121	R 4	R 262	R 22	R 410

Source: SAIS (2005)

An estimated 70% of domestic innovative firms in the agrofood processing sector have introduced new or improved goods; this is compared to about 80% of the foreign innovative firms that introduced new or improved goods. On the other hand, very few domestic firms, about 9%, introduced new or improved processes compared to 100% of foreign firms.

Table 4.15: **Innovation activities**

	New or improved goods		New or improved process	
	Domestic	Foreign	Domestic	Foreign
Number of firms that introduced new product/processes	303	8	37	10
Innovative firms in agroprocessing	434	10	434	10
Percentage of innovative agrofood processing firms that introduced new products/processes	70%	80%	9%	100%

Source: SAIS (2005)

Table 4.16 and 4.17 shows cooperation by type of partner and location. In Table 4.16, attention is drawn to domestic innovative firms and Table 4.17 shows only foreign innovative firms.

About 2% of the domestic firms cooperated with universities in South Africa, Asia and other countries, way below the 16% national average. The highest cooperation is between firms and their clients and customers, with about 6% of firms indicating such cooperation. Only innovative firms are included in this analysis. Non-innovative firms also have cooperation with other partners but for the purpose of this analysis were left out. The trends suggest that the agro-food domestic firms cooperate less on innovation activities than the national average.

Table 16: **Cooperation with other enterprises/institutions by location:Domestic firms**

	South Africa	Rest of Africa	Europe	USA	Asia	Other countries
Enterprises in same group	17 (4%)	0	0	0	0	0
Suppliers etc	17(4%)	0	12(3%)	0	2(0.5%)	
Clients& customers	25 (6%)	2 (0.5%)	10(2%)	2(0.5%)	2(0.5%)	2(0.5%)
Competitors	19(4%	0	0	0	2(0.5%)	0
Consultants	17(4%)	0	4(0.5%)	0	0	0
Universities etc	10 (2%)	0	0	0	10(2%)	8(2%)
Gov/public research institutes	8 (2%)	0	0	0	0	0

Source: SAIS (2005)

Table 4.17 below shows the cooperation of foreign firms with other institutions. Drawing attention to cooperation with universities, only 20% (which is only 2 firms) of the foreign firms cooperated with universities in South Africa, Rest of Africa and other countries respectively. About 40% of the foreign firms cooperated with suppliers, competitors and consultants in South Africa.

Table 4.17: Cooperation with other enterprises/institutions by location: Foreign firms

	South Africa	Rest of Africa	Europe	USA	Asia	Other countries
Enterprises in same group	2(20%)	2(20%)	2(20%)	2(20%)	0	0
Suppliers etc	4(40%)	0	0	0	0	2(20%)
Clients& customers	4(40%)	2(20%)	0	0	2(20%)	2(20%)
Competitors	2(20%)	2(20%)	0	0	0	2(20%)
Consultants	4(40%)	0	0	0	0	2(20%)
Universities etc	2(20%)	2(20%)	0	0	0	2(20%)
Gov/public Research institutes	2(20%)	0	0	0	0	2(20%)

Source: SAIS (2005)

Table 4.18 below shows how firms rated the importance of different sources of information. We draw attention to the ratings of universities/technnikons and scientific publications. None of the domestic and foreign firms rated universities as a highly important source of information, in contrast with that of scientific publications, whereby 27% of domestic firms and 20% of the foreign firms rated scientific publications as highly important. This suggests that for agro-food processing firms, publicly available information is more important than formal interactions with universities.

Table 4.18: **Importance of sources of information for agrofood processing firms**

	Domestic			Foreign		
	Low	Medium	High	Low	Medium	High
Enterprises within group	2	8	312	0	0	10
Suppliers	270	135	27	0	4	6
Competition	?	?	?	?	?	?
Clients	?	?	?	?	?	?
Consultants	14	123	12	6	4	0
Universities	23	8	0	4	4	0
Research Institutes	17	2	6	0	2	0
Conferences	133	14	6	8	0	0
Scientific publication	291	14	119	4	0	2
Industry associations	131	125	4	6	4	0

Source: SAIS (2005)

About 30% of the innovative firms in the agrofood manufacturing sector indicated that they participate in South African provincial markets. A larger share of 45% indicated that they participate in national markets of South Africa. Table 4.19 below shows the agroprocessing firms' detailed participation in markets.

Table 4.19: **Participation in markets: innovative firms**

Market	Number of firms	Percentage
South Africa (Provinces)	133	30%
South Africa (National)	199	45%
Rest of Africa	31	7%
Europe	21	5%
United states	10	2%
Asia	12	3%
Other countries	17	4%

Source: SAIS (2005)

In general, domestic agro-food processing firms appear to be less innovative and less likely to cooperate with other partners or to use universities as important sources of information than are all domestic firms. The very small group of foreign owned agro-food processing firms are more innovative and tend to cooperate to a moderate degree with a range of partners.

4.3 BRAZIL: PINTEC (2005) AND THE DIFFERENCES BETWEEN DOMESTIC AND FOREIGN FIRMS

The purpose of this section is to describe the innovative patterns in Brazil and to assess the state of cooperative arrangements for innovation in Brazil. Among the several types of cooperative arrangements taking place among agents in the Brazilian innovation system, we pay special attention to those ones established with universities, in order to understand the profile of firms that engage into cooperation with this specific agent.

The database applied in the paper is the latest Innovation Survey (PINTEC 2005) carried out in Brazil by IBGE. The survey presents a good amount of data on the innovation pattern of firms, also enabling the distinction of such patterns between domestic and foreign firms operating in Brazil. The survey also pays attention to the sources of information for innovation as well as to cooperative arrangements with the same intent. We apply the PINTEC survey data to test which firm's characteristics might increase their propensity to engage in cooperation with universities, a partner that is of special importance when we talk about new technologies, innovation and technological development in immature national innovation systems.

The section is divided as follows: after this introduction, section 4.3.1 discusses the general patterns of innovation from Brazilian firms; section 4.3.2 descries how firms in Brazil engage in cooperative arrangements for innovation. Section 4.3.3 presents the econometric test for the characteristics that enhance a firm's propensity to engage in cooperation with universities. The final section discusses our findings.

4.3.1 Patterns of Innovative Activities in Brazil

The Brazilian Innovation Survey (PINTEC) carried out by IBGE contains important information on the origins of information for innovation, as well as on the cooperative arrangements that took place with the purpose to innovate. The universe of the 2005 edition of the survey comprises 89.162 domestic firms and 1.893 foreign firms, summing up 91.055 firms. The group of innovative firms is much smaller: 29.951 firms (32,9% of total) declared having performed product and/or process innovation between 2003 and 2005.

According to PINTEC, and in line with the guidelines of the Oslo Manual, the concept of innovative activities comprise R&D (basic and applied research, experimental development) and other non-R&D related activities, such as the external acquisition of goods, services and knowledge (IBGE, 2007: 21). Therefore, among R&D expenditures, the survey considers internal as well as external R&D, equipment & machinery acquisition, royalties and other types of knowledge access; and training.

The survey reveals that a great amount of innovation expenditures from Brazilian firms takes place through the acquisition of mew machinery and equipment. From the total of innovative firms, only 6.021 (20%) declared that their R&D activities had a strong or average role for innovation (IBGE, 2007).

There are many differences in the patterns of innovation between domestic and foreign firms operating in Brazil. Out of the more than 89 thousand domestic firms, 5.537 have declared expenditures in internal R&D – a share of 6,2 percent of firms; foreign firms that declared R&D spending totalized 631 firms, a share of 33,3 percent.

Table 4.20: absolute R&D expenditures of firms, 2003-05 (in R$ 1.000)

	Internal R&D	External R&D	Total	%
Domestic	6,698,048	547,843	7,245,891	59.18%
Foreign	3,689,442	1,308,781	4,998,223	40.82%

Source: PINTEC, 2005.

Table 4.21 presents the sectors that concentrate R&D expenditures among domestic and foreign firms in Brazil. For the former, the leading sector in R&D expenditures is oil & gas whereas for the latter the leader is the automotive sector.

Table 4.21. R&D expenditure by ndustrial sectors and capital owenership (in R$1000)

	Domestic Firms		Foreign Firms	
	Internal R&D	External R&D	Internal R&D	External R&D
Total Manufacturing	3,877,494	388,148	3,157,859	555,922
Food & beverages	187,929	13,067	105,621	6,551
Tobacco		1,612	20,792	x
Textiles	53,568	2,296	2,033	781
Clothing	27,936	1,269	x	
Leather products	66,373	6,672	x	
Wood products	19,785	644		
Pulp and paper	61,390	3,102	23,975	3,531
Edition& printing	8,058	570	10,711	x
Oil & Gas	944,785	133,157	5,138	1,156
Chemicals and pharmaceuticals	453,613	34,944	410,762	136,415
Rubber and plastics	97,671	16,912	96,902	2,922
Non metallic materials	83,750	7,831	28,664	820
Metallurgy	107,385	4,120	70,022	15,405
Metal products	56,421	4,680	30,762	557
Machinery and equipment	220,852	10,113	150,200	12,941
Informatics equipment	54,753	21,997	98,628	13,066
Electric devices & machinery	145,657	5,568	249,181	11,763
Electronic equipment	134,045	28,736	277,307	157,228
Medical instruments	149,854	5,757	20,477	x
Automotive and autoparts	173,233	21,654	1,519,320	185,844
Other transport equipment	750,091	58,838	24,079	x
Furniture	80,345	4,609	6,558	4,518

Source: IBGE: PINTEC, 2005.

The sector with the largest number of firms engaged in cooperative arrangements is chemical and pharmaceuticals. In the services sectors – for the first time surveyed in PINTEC – firms from IT services lead (Table 4.22)

Table 4.22: Innovative and Cooperative firms by sector

Sector	Innovative	Cooperative	% C/I
Total Of Industry	29,951	2,139	7.1
Food and beverages	3,771	249	6.6
Clothing	3,403	109	3.2
Metal products	2,668	173	6.5
Furniture	2,304	43	1.9
Machinery and equipment	2,282	202	8.9
Chemical & pharmaceutical products	1,900	**314**	16.5
IT services	2,197	**425**	19.3
Total of Services	2,418	582	24.1

Source: IBGE, PINTEC 2005.

The innovative activities of domestic and foreign firms are different in terms of the types of innovation each of them carry out. Domestic firms innovate more in processes (26,4 % vis-à-vis 18.9% for product innovation) (IBGE, 2007); whereas foreign firms have a balance between process and product innovation (around 50% for each). The sectors that carry out more product innovation are different by capital ownership: domestic, they are leather and shoes, in foreign capital, metallurgy and automotive – these last two also the sectors that concentrate the biggest number of foreign firms in Brazil.

Moreover, PINTEC reveals that product innovation tends to be a more cooperative activity than process innovation in Brazilian firms (Table 4.23). This might suggest that firms still rely on secrecy rather than partnership when bringing new products to the market; it could also suggest that firms look for complementary knowledge in the innovation they do most: 27 percent of firms reported undertaking process innovation, vis-à-vis 19.5 percent for product innovation. Nevertheless, this sound counterintuitive, since product innovation demands broader knowledge and would therefore benefit from different partners in R&D collaboration (Un, Cuervo-Cazurra and Azakawa, 2009).

Table 4.23: Main responsible for the development of the innovation (industrial firms) – %

	Product	Process
Firm alone	89,5	9,2
Another firm in the group	1,2	0,7
Firm in cooperation with other firms/ institutes	5,0	3,0
Other firms and institutes	4,0	87,1

Source: IBGE,PINTEC 2005.

Table 4.24: Degree of newness according to capital ownership

New to firm		**New national market**		**New World**	
Domestic	Foreign	Domestic	Foreign	Domestic	Foreign
14.486	539	1.978	337	363	81

In Brazil, it still predominates what can be called 'defensive innovation': innovation done in order to follow the market trends, to copy the leaders in the sectors; more disruptive innovation (products and processes new to the national market or to the world) takes place to a much smaller degree.

In resume, PINTEC 2005 shows that innovation is gaining importance among Brazilian firms, but also that there is a huge opportunity for improving. Firms can innovate more and also be bolder in their innovative efforts. Next section deals with a special way of enhancing innovation efforts and results: innovation through cooperative partnerships.

4.3.2 General Trends in Cooperation

According to the latest innovation survey, Brazilian firms registered a rise in cooperative activities, if compared the previous years surveyed (2003): the share of firms that declared to have participated in a cooperative arrangement, which was of 3.8 percent in 2001/2003, reached 7.2 percent, totalling 2,139 firms (IBGE, 2007; table 4.21). The growth was even stronger among small firms (up to 500 employees). In firms with more than 500 employees, there was a small decline in the percentage of cooperative firms.

Though a growing share among innovative firms, the share of cooperative firms in Brazil is much lower than those observed in surveys of developed countries; a recent study from OECD pointed that one in every ten European firms cooperated in the period 2002-04, or one in every four of the innovative firms (OECD, 2007). In Germany, the share of cooperative firms reached 50 percent (Fritsch and Lukas, 2001). Brazilian firms from services sectors have a share of cooperation of 24 percent (IBGE, 2007). The trend observed in Brazil, however, is similar to other developing

economies – the neighbour country Argentina also revealed a small tendency to cooperate for innovation, and when Argentine firms do so, they chose mostly suppliers and customers as partners (Lugones and Suarez, 2007).

Vertical partnerships – the ones involving clients/ consumers and suppliers – are the most frequent type of cooperation among Brazilian firms. The second most usual type of cooperation is between firms and universities /research institutes – those are important partners for 29.5 percent of cooperative firms in Brazil. Partnerships with competitors are the less frequent cooperation, taking place in only 15 percent of associations (Table 4.22). Complementarily, the next table describes types of cooperation among different agents and types of activities – either R&D or other types of partnerships (technical assistance, training, industrial design, tests).

Table 4.25: Cooperation for Innovation - by type of partners and R&D partnerships (% of cooperative firms)

Partner	R&D Partnership	%	Other Partnerships	%
Clients/consumers	773	36.1%	790	36.9%
Suppliers	747	34.9%	1083	50.6%
Competitors	146	6.8%	246	11.5%
Other firm group	294	13.7%	261	12.2%
Consultancies	339	15.8%	433	18.9%
Universities/Research institutes	663	31.0%	404	18.9%
Training Centres	207	9.7%	474	22.2%

Source: IBGE, PINTEC 2005.

As expected, most firms in Brazil associate with partners located domestically. The most frequent partnership with foreign partners is that of foreign firms and other firms from the group (Table 4.26).

It is worth noticing that 'other firms from the group' have a very low importance as a source of information, which can be understood by the fact that, even though there are several large domestic groups in Brazil (originated from local, usually family capital) their innovative activities tend to be concentrated in only one facility. On the other hand, when one looks only to foreign firms, the importance of other firms in the group for innovation are evident (Table 4.30).

Table 4.26: types of cooperation by capital ownership and location of partner

Partner	Domestic		Foreign	
	Local	Abroad	Local	Abroad
Customers	1131	57	143	31
Suppliers	1087	107	138	51
Competitors	317	23	23	10
Another firm of the group	79	39	23	220
Consultancies	428	22	53	11
Universities	599	14	113	-
Training Centers	461	-	58	4

Source: IBGE, PINTEC 2005.

In general, cooperative arrangements for innovation undertaken by Brazilian firms follow the same patterns seen in other countries. Everywhere, it is the most knowledge-intensive sectors those to lead cooperation. However, both the share of innovative firms and of cooperative firms in Brazil is much lower than those of developed nations. The role of university as an important source of information and partnerships for innovation is still modest – facts that stress the fragility of the innovation system in Brazil and its immature relationships among the diverse actors.

Regarding government support policies, the most used – for both domestic and foreign firms – was the funding of R&D and technological innovation projects. The benefits of the Innovation Law, the Informatics Law, as well as R&D project funding when jointly undertaken by firms and universities/research institutes, still have a limited scope, due to not only the small innovative propensity of Brazilian firms but also to the lack of information on how such incentives work and can be accessed. Although also low, foreign firms make relatively more use of innovation support programs (Table 4.27).

Table 4.27: Use of Innovation Support Programs, by capital ownership

Program	Domestic	% of firms	Foreign	% of firms
Innovation Law	164	0.184%	58	3.064%
Informatics Law	290	0.325%	54	2.853%
R&D Projects; U-I partnerships	420	0.471%	53	2.800%
Funding of R&D/ Innovation projects	3828	4.293%	102	5.388%
Researcher in-company scholarship	63	0.071%	11	0.581%
Venture Capital	395	0.443%	6	0.317%
Total of Firms by ownership	89162		1893	

Source: IBGE, PINTEC, 2005.

Next section takes a further look on the state of university-industry cooperation in Brazil, based on the 2005 innovation survey data.

4.3.3 University – Industry Cooperation in Brazil

The database from the Brazilian innovation survey provides a portrait of the current state of cooperative agreements between firms in Brazil, and also specific information on cooperative agreements between firms and universities.

Research and development (R&D) activities are the main type of activity in which firms cooperate with universities/research institutes. But there are several other types of relationships that are important means of interaction university-industry (Table 10). Firms cooperate with universities in various sectors; the leading sector in number of partnerships is the chemical sector, both for R&D and other activities; followed by food and beverages (Table 4.28).

Table 4.28: University-Industry cooperation in Brazil - by selected sectors (2003-05)

Industry	R&D	Other activities
Total Of Industry	**663**	**404**
Food and beverages	83	42
Leather products	35	37
Electrical equipment	38	25
Rubber and plastic	76	19
Machinery and equipment	46	46
Telecom equipment	39	12
Chemical & pharmaceutical products	134	63
Vehicles	27	15
Total of Services	**128**	**120**

Source: IBGE, PINTEC 2005.

Table 4.29: Types of cooperative activities with Universities, by capital ownership

	Domestic	% *	Foreign	%**
R&D	361	0,4%	101	5,3%
Tec. Assistance	71	0,1%	14	0,7%
Training	180	0,2%	30	1,6%
Industrial design	60	0,1%	8	0,4%
Tests	336	0,4%	76	4,0%
Others	185	0,2%	31	1,6%

Source: IBGE, Innovation Survey, 2005.

* share in total domestic firms (89162)

** share in total foreign firms (1893)

Regarding the sources of information for innovation, Brazilian firms declared to resort more to clients and suppliers; competitors come as the third source. Universities are ranked fourth as a source of knowledge for innovation (Table 4.28).

Table 4.30: Sources of Information for Innovation, by capital ownership

	Domestic	**%**	**Foreign**	**%**
Other firms/ group	563	1,0	852	45,0%
Clients	18.881	21,0	872	46,1%
Suppliers	19.740	22,0	789	41,7%
Competitors	13.749	15,0	495	26,1%
Consultancies	3.800	4,0	262	13,8%
Universities	3.686	4,0	231	12,2%
Training centers	4.832	5,0	231	12,2%

Source: IBGE, PINTEC 2005.

Due to its relevance in the economic output, it is important to understand how innovation and cooperation work in foreign firms operating in the domestic markets. The numbers show that the share of cooperative firms is still very low in Brazil, both for domestic and foreign firms (though the latter tends to cooperate slightly more than domestic firms).

Rather than emphasizing the negative size of such small number of cooperative arrangements for innovation, this paper wants to highlight the big possibilities that exist to Brazilian firms that decide to undertake R&D initiatives jointly with other agents (firms, universities or research institutes). The current scenario is one of an increasing awareness of firms of the benefits of innovation for their businesses (as the subject becomes more debated in specialized medias, conferences and study groups, and also strongly fostered by government policies); the increasing awareness of the benefits of innovation also lead firms to learn that they do not need to undertake such entrepreneurships alone, but rather can achieve more by making this an open process and incorporating external sources and knowledge (Chesbrough et al., 2006)

4.3.4 Firms and the Propensity to Engage in U-I Cooperation: an empirical analysis

This section assesses the characteristics of firms that cooperate with universities – more specifically, which characteristics might influence on the propensity to cooperate with universities. Other studies have done similar efforts to profile this specific behaviour of firms. For instance, Segarra-Blasco et al. (2008) carried out a study using data from the Spanish CIS and found out that large Spanish firms that undertake intramural R&D and cooperate with other agents in the innovation system have a higher propensity to engage in cooperative arrangements with universities.

The main underlying assumption is that the hypothesis raised for university-cooperating firms also holds for innovative firms as well, since the former is expected to be a sub-unit of the latter. The relationship between innovation and firm size, R&D expenditure, level of human resources, have already proved to be positive in several studies. We then extend some of these assumptions in order to check whether they hold for the more specific case of cooperation, and university-industry cooperation in Brazil. The hypotheses to be tested are listed in the Box below.

Box 4.1: hypotheses

H1: Cooperation with universities increase with firm size (measured in terms of net sales revenues)

H2: Intramural R&D activities increase the propensity to cooperate;

H3 Continuous R&D activities increase the propensity to cooperate with Universities.

H4: The higher the degree of newness of the product, the higher the propensity to cooperate with universities

H5: Firms utilizing innovation support programs from the government have a higher propensity cooperate with universities

H6: Engagement in cooperation with other agents increase the propensity to cooperate with universities

H7: A higher number of employers with post-graduation degrees increase the propensity to cooperate with universities

H8: Firms engaged in product innovation have a higher propensity to cooperate with universities more

In order to test the hypotheses above, we use a set of explanatory variables available from the survey: firms' characteristics, sources of innovation, use of public funds and cooperation partners (Box 4.2).

Box 4.2: Definition of the independent variables

Variables	Description
Firm characteristics	
Net sales revenues	Log of sales revenues
Domestic	Dummy=1 for domestic firms
product innovation	Dummy=1 if the firm has performed product innovation
New national	Dummy=1 when innovation is new to local market
New world	Dummy=1 when innovation is new to world
masters employees	Log of the number of employees with at least a master degree
Innovation sources	
Intramural R&D	Log of internal R&D expenditures
Extramural R&D	Log of external R&D expenditures
Continuous R&D	Dummy=1 if R&D is a continuous activity
Use of public funds	
Gov support	Dummy=1 if firm obtained funding from any government program
Public_fund	Dummy=1 if firm innovation was carried out with public funds
Cooperation Partners	
Vertical cooperation	Dummy =1 if firm cooperated with clients and/or suppliers
Group	Dummy=1 if firm cooperated with other firm from the group
Competitors	Dummy=1 if firm cooperated with competitors

The variables 'net sales revenues' and 'domestic' are used as control variables, since most companies in the sample share these characteristics.

4.3.5 Results

Table 4.31 presents the coefficients of the probit regression, and give some very interesting information on the profile of firms that cooperate with universities. First, the size of the firm does

not seem to exert any influence on the propensity to cooperate, which leads us to reject hypothesis 1. Intramural R&D expenditures have a positive effect on the engagement of cooperation with universities, but the same effect was observed from extramural R&D. That leads us to accept hypothesis 2, and reinforces the importance of R&D expenditures as a generator of innovative efforts and cooperative arrangements with universities. Continuous R&D also presented a positive effect on the propensity to engage in cooperation with universities, and hypothesis 3 is also accepted.

Whereas product innovation does not have a significant effect over cooperation, innovation new to the world has a significant positive effect. This suggests that, the more breakthrough the innovative effort is, more firms are inclined to undertake innovative efforts jointly with universities and research institutes. This is also in line with the information on Table 4, which states that 89,5percent of firms affirm to carry out product innovation by themselves. Process innovation, on the other hand, is an activity that prompts a higher cooperative behaviour among Brazilian firms. Hence, we accept hypothesis 4 and reject hypothesis 8.

The utilization of government supported R&D activities also have a positive effect on cooperation with universities – possibly due to the incentives given to joint R&D projects with universities and/or scholarships grants for researchers working within the firm - and therefore we accept hypothesis 5. This is similar to results found for other countries, where government funding also revealed a positive relationship with university cooperation (Segarra-Blasco et al., 2008). On the other hand, the presence of publicly funded R&D showed a negative effect on the probability to cooperate with universities.

Another interesting result is the positive effect that the number of employees with at least a master degree played on the propensity to cooperate with universities (accepting thus hypothesis 7). Higher skilled labour can be seen as a proxy for the technological level of the firm, and therefore it is reasonable to expect that higher technological firms do cooperate more with universities. Moreover, it is reasonable to affirm that higher skilled personnel contribute to improving the capacity of absorbing knowledge from external sources.

Moreover, in general terms, cooperation with other partners showed a positive impact on the propensity to cooperate with universities. The positive effect is stronger for vertical partnerships (clients or suppliers), but it is also true for cooperation with competitors and other firms from the group. Hypothesis 6 is therefore accepted.

Table 4.31: Cooperation with Universities (probit model)

Parameter	Estimate (SE)
Intercept	- 3.2068 ***
	(0.2089)
Vertical Cooperation	1.4553***
	(0.0503)
Net Sales Rev	0.0152
	(0.0112)
Cooperation Group	0.2429**
	(0.1087)
Cooperation Competitors	0.2272 **
	(0.0840)
MastersEmploy	0.3382 ***
	(0.0477)
Domestic	0.2439 *
	(0.0963)
Innov_product	-0.0626
	(0.0524)
Intern R&D	0.0182 **
	(0.00612)
Extern R&D	0.0345 ***
	(0.00563)
R&D continuous	0.3125 ***
	(0.0752)
New world	0.7724 ***
	(0.0944)
New national	0.0177
	(0.0637)
Gov_support	0.4898 ***
	(0.0561)
Public_fund	- 0.1954 *
	(0.0720)
Hosmer-Lemeshow GOF test	DF (Pr> Chi2)
Chi2 34.0502	8 (<.0001)

* significance at 10%; ** significance at 5%; *** significance at 1%

Our control variable for firm ownership showed that domestic firms have a positive propensity to engage in cooperative agreements with universities. Such result can be associated with the fact that domestic firms are the absolute majority in the survey, which can bias such result. Therefore, such a result should be interpreted with caution. Cooperation among universities and the industry in Brazil have a supporting policy since 1995, with PITE (Program of Partnerships for Technological Innovation), funded by Fapesp. The program funds exclusively joint projects between firms and universities, and many firms, such as Natura, Oxiteno, Dedini and Braskem have benefited from the program26.

4.3.6 Concluding Remarks

The purpose of this paper was to give an overview of how cooperative agreements take place between Brazilian firms and other agents of the innovation system, with a special focus on industry-university partnerships. The numbers from the recent innovation survey from Brazil show that the trend signals towards an increasing occurrence of cooperative agreements for innovation between the various agents of the national innovation system, especially between firms and universities.

[26] For information on ongoing and finalized project, see http://www.pesquisaapoiada.fapesp.br/pite/index.

However, as innovation, cooperation between universities and enterprises in Brazil are still low and has huge opportunities to grow.

Cooperation is carried out by 7.2 percent of innovative firms in Brazil. Relative to the number of firms, foreign firms cooperate more. This is also true for university-industry cooperation. Vertical cooperation is the most frequent type observed in Brazil; after clients and suppliers, universities are the preferred partners from Brazilian firms.

The probit analysis showed that, the higher the degree of newness of the innovation aimed by the firm, the more they resort to universities as partners for innovation. The presence of skilled labour is another factor that increases the propensity to cooperate with universities.

4.4 SOUTH AFRICA AND BRAZIL: FOREIGN R&D AND INTERACTIONS

Two key conclusions may be drawn from this chapter, summarizing data regarding the role of foreign R&D in both national economies and how those R&D investments impact on knowledge flows.

4.4.1 Foreign R&D

Analysis of both innovation surveys demonstrates the importance of foreign R&D investments for these two peripheral countries.

Table 4.32A and 4.32B presents data for South Africa. Table 4.32A shows that in manufacturing, the sector with the largest total R&D investment, the R&D spend of foreign-owned firms comprises 19.9%. Manufacturing is the sector with the highest R&D investment by foreign-owned firms. Table 4.32B disaggregates the agroprocessing sector, reflecting that foreign R&D is a lower 7.8% of the sectoral R&D spend.

Table 4.32-A: South Africa

R&D by Capital Ownership

	Domestic	Foreign	Total
Mining	820	16	836
Manufacturing	2426	603	3029
Electricity, Gas etc	13	0	13
Wholesale and retail trade	1497	337	1834
Transport and communication	263	57	320
Financial intermediation	33	0	33
Services	420	376	796
Other business activities	1018	0	1018
Total	6490	1391	7881

Table 4.32-B: South Africa - AGROPROCESSING

Agroprocessing expenditure on R&D (R Millions

	Internal	External	Machine	Knowledge	Total
Domestic	105,0	4,0	246,0	22,0	377,0
Foreign	16,0	0,4	16,0	0,3	32,0
Total	121,0	4,4	262,0	22,3	409,0

Table 4.33 presents data for Brazil, showing that the share of foreign-owned firms in manufacturing sector R&D is 46.5%. The automotive sector stands out with a significantly high share of foreign-owned firm investment in R&D: 89.7%.

Table 4.33 - Brazil: Domestic and Foreign R&D, 2005 (R$)

	Domestic	Foreign	Total
Total Manufacturing	4.265.642	3.713.781	7.979.423
Food & beverages	200.996	112.172	313.168
Tobacco	1.612	20.792	22.404
Textiles	55.864	2.814	58.678
Clothing	29.205	-	29.205
Leather products	73.045	-	73.045
Wood products	20.429	-	20.429
Pulp and paper	9.241	27.506	36.747
Edition& printing	8.628	10.711	19.339
Oil & Gas	1.077.942	6.294	1.084.236
Chemicals and pharmaceuticals	488.557	547.177	1.035.734
Rubber and plastics	114.583	99.824	214.407
Non metallic materials	16.206	29.484	45.690
Metallurgy	107.797	85.427	193.224
Metal products	56.889	31.319	88.208
Machinery and equipment	230.965	14.443	245.408
Informatics equipment	76.750	111.694	188.444
Electric devices & machinery	151.225	260.944	412.169
Electronic equipment	162.781	434.535	597.316
Medical instruments	155.611	20.477	176.088
Automotive and autoparts	**194.887**	**1.705.164**	**1.900.051**
Other transport equipment	808.929	24.079	833.008
Furniture	84.954	11.076	96.030

These data suggests that R&D investment by foreign-owned firms is important in the manufacturing sector in both countries, ranging from 19.9% to 46.5% of manufacturing R&D.

4.4.2 Interactions with Universities and Other Sources Of Knowledge

How does such foreign R&D investment impact on flows of knowledge? The innovation survey data can inform how domestic and foreign R&D differs in terms of the main sources of information for innovation, particularly, enterprises in the same group, and universities and research institutes.

Table 4.34 shows that, for South Africa, 5% of foreign firms use universities (and 4% use research institutes) as sources of information, but 31% use enterprises in the same group. South African

domestic firms rely relatively more on universities and research institutes as sources of information (respectively 16% and 14%) and relatively less on enterprises in the same group (23%).

Table 4.34 – South Africa: sources of information for innovation

	Domestic	Foreign
Enterprises in same group	3 460(23%)	424(31%)
Suppliers of equipment etc	4 353(29%)	470(34%)
Clients/customers	5 513(37%)	480(35%)
Competitors	4 284(29%)	450(32%)
Consultants	2 453(16%)	458(33%)
Universities etc	2 433(16%)	72(5%)
Research institutes	2 092(14%)	56(4%)

Table 4.35 shows that, for Brazil, 20.5% of foreign firms use local universities and 44.1% of foreign firms use other firms of the group (either abroad or local), as a source of information for innovation. Regarding domestic firms, a lower 14.6% use local universities and only 2.9% another firm of the same group. Another difference shown in Table 4.35 is the use of foreign universities: only domestic firms mention this cross-border interaction. As presented in chapter 1, Figure 2.2 shows a combination of type 2 (local firms with international interactions) and type 4 (transnationals interacting with host country universities – but in this case the relationship with home country universities is organized by the corporation headquarters).

Table 4.35 - Brazil: sources of information for innovation

	Domestic		Foreign	
Partner	Local	Abroad	Local	Abroad
Customers	1131	57	143	31
Suppliers	**1087**	**107**	**138**	**51**
Competitors	317	23	23	10
Another firm of the group	79	39	23	220
Consultancies	428	22	53	11
Universities	**599**	**14**	**113**	**-**
Training Centers	461	-	58	4
Total	4102	262	551	327

Source: IBGE, PINTEC 2005.

There are clearly differences in the scale of interactions between South Africa and Brazil, but the convergent trends between the two countries are of greater interest. What is a common trend is that TNC subsidiaries rely on knowledge flows from within their group to a greater extent than domestic firms do. In both countries, the TNCs subsidiaries appear to rely more on their own internal networks than on universities or research institutes. These trends may be in line with what would be

expected from the review of the literature on GINs, and from previous studies about the differences between domestic and foreign firms within immature NSIs (Rapini et al, 2009; Neto et al, 2010). They highlight the importance of investigating the nature and dynamics of type 4 interactions – TNCs interacting with both home and host country universities - in greater depth.

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CHAPTER 5: INTERACTION BETWEEN NATIONAL AND MULTINATIONAL FIRMS AND BRAZILIAN UNIVERSITIES

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5.1 INTRODUCTION

The literature on multinational corporations (MNCs) emphasizes that innovation is one of the least internationalized segments within its structure, being one of the last activities to be transferred to other countries following activities such as production and marketing (UNCTAD, 2005). With regards to the nature of research and development (R&D) activities conducted in subsidiaries, it is possible to observe that a significant proportion of them is associated with the adaptation and modification of products and processes to the needs of local markets (OCDE, 1998, DUNNING, 1992; UNCTAD, 2005; DE NEGRI, 2007). However, some evidence suggests a growing importance of R&D activities carried out by MNC subsidiaries that have as their aim the acquision of technological spill-overs, both from the local base of knowledge and from specific firms (CRISCUOLO *et al.*, 2005). Throughout the world, strategies of technological pursuit and rationalization of R&D activities, seeking economies of scale and scope, have become increasingly relevant in the decision of MNCs to invest in R&D abroad. The internationalization of these firms' R&D activities has resulted in an increase in the responsibilities and the technological capabilities of subsidiaries.

In the Brazilian case, data from the 2005 Survey of Technological Innovation (PINTEC/IBGE) show that, in terms of foreign firms, spending on the internal R&D of the 631 firms that had carried out the activity was approximately 3.7 billion *reais* (2.2 billion dollars)[27]. The main sector where these activities occurred was among companies focused on the manufacture of chemical products. External R&D took place in 231 foreign firms, mainly in manufacturing but also among companies involved in the manufacture of chemical products. In relative terms, it appears that around 50% of private investments in R&D carried out by the Brazilian industry in 2005 were made by foreign firms' subsidiaries in Brazil (DE NEGRI, 2007). This data shows efforts made by MNCs in developing technology in the country. Nevertheless, it is still necessary to find out whether such efforts involve cooperation with actors that compose the Brazilian system of innovation.

Within this context, this paper aims at investigating the patterns of interaction between national corporations (NCs) and MNCs located in Brazil with universities and public research institutes (PRIs) in the country. In order to do so, this study used a database consisting of survey data gathered from 319 questionnaires completed in 2009. To fulfill this purpose, this text is organized into five sections not including this introduction. The second section presents a literature review that discusses features of MNCs regarding their interaction with universities and PRIs in mature and immature systems of innovation. The literature also addresses the issue of internacionalization of R&D and the techonological performance of MNC´s located in Brazil The methodology presented

[27] According to the website XE – Universal Currency Converter, 1 USD = 1,67 BRL in March 27, 2011.

in the third section explains the research behind the survey, from where the data was extracted and MCA was carried. The fourth section shows the existence, or lack thereof, of different patterns of interaction between universities/PRIs and NCs and MNCs, based on the results obtained by the descriptive data analysis and from the MCA method. Finally, the last section contains final remarks about the work.

5.2 MULTINACIONALS, LESS DEVELOPED SYSTEMS OF INNOVATION, AND THE INTERNATIONALIZATION OF R&D

5.2.1 MNCs, National Systems of Innovation and University-Firms Interaction

The interaction between universities/PRIs and firms, in both NCs and MNCs, refers to the degree of development of National Systems of Innovation (NSIs). NSIs are composed of a set of actors such as universities, research institutes, the financial system and firms, to name a few, through which their interactions foster the process of technological innovation. In this context, decisive importance is attached to the interaction between scientific and technological production, which demonstrates that universities and PRIs involved in the production of basic and applied science are fundamental NSI actors. This is due to the fact that such institutions act in order to enhance and complement the innovative activities undertaken by the industry.

In the scientific sphere, universities and PRIs play a central role in the creation and diffusion of knowledge through traditional functions such as education and basic research. In that way, they renew the stock of existing knowledge in the country where they play an extremely important role in the technological development, whether in educating and training the industry's scientists and engineers, or as source of research findings and techniques relevant to the industry's technical advancement (NELSON e ROSENBERG, 1993). According to Albuquerque (1999), in the case of peripheral economies, the scientific infrastructure can act as an "antenna" for the identification of technological opportunities, connecting such NSIs to international scientific and technological flows. Accordingly, the main contribution of the university system to less developed economies would lie in its support of the catching up process.

In the technological sphere, firms generally do not have all the necessary resources to innovate and thus need to acquire knowledge from external sources such as universities and PRIs. The literature in this matter highlights the existence of some structural characteristics that are related to the absorptive capacity of these agents and to their search for narrow interactions with external partners28. Thus, it is important to highlight that, in order for knowledge transfers to occur, the firm needs to have some absorptive capacity. Large corporations like MNCs have such a feature and, due to their economic power and scale, are usually among the chief innovative agents in an international context (UNCTAD, 2005).

[28] Empirical studies on cooperation pattern of firms with external partners show that firms that conduct R&D tend to cooperate more than those that do not (THETER, 2002, KUPFER e AVELLAR, 2009). In addition to that, they suggest that the cooperation with universities tend to increase with the firm's size (TETHER, 2002; KUPFER e AVELLAR, 2009; KRUSS *et al.,* 2009) and that the chances that the firm will cooperate also increase when it has foreign capital (TETHER, 2002; KUPFER e AVELLAR, 2009).

Regarding the connections between these two spheres, Albuquerque et al. (2008) highlighted that it is necessary to distinguish university-firms interaction between mature and immature NSIs. The literature on mature NSIs (ALBUQUERQUE, 1999) shows that in developed countries, it is possible to identify patterns of interaction between the scientific and technological dimensions that are much more complex than the linear process in which basic research leads to applied research, which, in turn, generates an innovation that results in economic profit (NARIN et al., 1997). Flows of information and knowledge take place in both directions, in bidirectional interactive relationships that promote virtuous circles in the production and diffusion of knowledge. On one hand, universities and PRIs produce knowledge that is absorbed by the productive sector, as demonstrated by Narin et al. (1997), Klevorick et al. (1995) e Cohen et al. (2002). On the other hand, firms accumulate technological knowledge that provides subsidies for scientific elaboration, as described by Rosenberg (1992). In most countries with a mature NSI there is, therefore, a complementarity between the production of basic research and the demand of firms' production as well as stronger relationship channels between the parties, features that facilitate the communication between them (ALBUQUERQUE et al., 2008; NARIN et al., 1997).

The peculiarities of immature NSIs, like the Brazilian one, namely the existence of "partial connections" between the scientific infrastructure and technological activities, limit the interaction between their various constituents (ALBUQUERQUE, 1999; 2003). This is because the flow of knowledge between science and technology is restricted to a small number of connections or interactions that have, in successful cases, a localized and disperse character as occurs in developing countries such as South Africa and Brazil (RAPINI 2007; ALBUQUERQUE et al., 2008; SUZIGAN e ALBUQUERQUE, 2008).

5.2.2 The Process of Internationalization of R&D and Technological Performance of MNCs in Brazil

It is a fact that firms' R&D activities are increasingly internationalized, although they remain restricted to a small number of countries (CALRSSON, 2006; UNCTAD, 2005). As maintained by authors like Patel e Vega (1999), R&D activities of MNCs, which are increasingly taking place outside their home country, are still very limited to developed countries, and more specifically to the triad, namely the United States, Japan and Europe. In the case of developing countries, R&D activities of these firms are almost always linked to product and process adaptation to local markets (PEARCE, 1999; UNCTAD 2005).

This decentralization process of technological activities is very much related to the current strategies of MNCs which are linked to the necessity to protect, diversify and complement their technological advantages, as well as to develop other ones (CANTWELL, 1994). In the opinion of Pearce (1999), the motivations for the decentralization of R&D by MNCs involve the restructuration of subsidiaries as a way to incentivize the firm's competitive performance and even the development of distinct technological expertise in a larger number of countries. Among these are some developing countries where, besides product adaptation, R&D activities of MNCs include more complex practices similar to work done in more advanced countries. However, developing countries and economies in transition that are effectively participating in the process of the internationalization of R&D, especially Asian countries like South Korea, Singapore, Taiwan (China), Hong Kong (China) and Malaysia, are still few in number (OECD, 2008).

Regarding the characterization of technological activities of MNCs' subsidiaries in Brazil, studies based on innovation surveys from PINTEC/IBGE (QUEIROZ e CARVALHO, 2005; ARAUJO, 2005; RUIZ e BHAWAN, 2010) and from the 'São Paulo Economic Activity Research'[29] - PAEP/SEADE[30] (QUADROS et al., 2001; COSTA e QUEIROZ, 2002; KANNEBLEY JÚNIOR e SELAN, 2007) show that these firms, taken together, are very active in R&D and account for a significant portion of the technological effort of firms operating in the country[31].

Data on patents can be used for the same purposes. Albuquerque (2000) and Biazzi and Albuquerque (2001) demonstrate that foreign capital firms have an important participation in Brazilian technological activities, as measured by domestic patents (patents granted to residents) by the 'National Institute for Industrial Property'[32] (INPI)[33]. However, the authors identify a considerable imbalance between stocks of patents "from outside" (non-residents patents deposited in Brazil by global firms) and stocks of patents that were deposited by their subsidiaries, indicating a low relative internalization of technological activities.

The literature that attempts at characterizing technological activities carried out by local MNCs subsidiaries through in depth case studies and surveys of firms, also identifies firms that carry out some type of technological activity in the country. Nevertheless, some authors advocate the view that a considerable portion of MNCs' subsidiaries in Brazil carry out primarily technological activities of development (that is, the "D" of R&D) (DIAS, 2003; CONSONI, 2004; QUEIROZ e CARVALHO, 2005; GALINA et al., 2005; CONSONI e QUADROS, 2006; CAMILLO et al., 2008; PARANHOS e HASENCLEVER, 2009). For instance, Camillo et al. (2008) note that in some of these firms, development activities are not even continuous.

It is noteworthy that some authors (QUEIROZ e CARVALHO, 2005; CAMILLO *et al.*, 2008) argue that it is rare to have cases in which R&D functions of a subsidiary in the country are diversified enough to characterize the presence of activities of internal technological research. However, other studies such as Gomes *et al* (2010a; 2010b) relativize this issue, showing that most subsidiaries that were surveyed carry out both activities of research and development in Brazil. In addition to that, Camillo *et al.* (2008) highlights that within subsidiaries of MNCs that carry out technological research in Brazil, these activities mostly take place sporadically.

Furthermore, the literature shows that technological activities of subsidiaries operating in Brazil are primarly focused on adapting products and processes to local and, in some cases, regional markets (QUADROS *et al.*, 2001; ARAUJO, 2005; QUEIROZ e QUADROS, 2005; GALINA *et al.*, 2005; CAMILLO *et al.*, 2008; STRACHMAN e AVELLAR, 2008). Therefore, it can be argued that the participation, in Brazil, of subsidiaries developing relevant research for global technological development or for the firm in a global context is not very significant.

[29] In Portuguese: 'Pesquisa de Atividade Econômica Paulista.'
[30] Both innovation researches have the Oslo Manual as their conceptual and methodological reference.
[31] It is important to highlight that these articles are based on specific editions of PINTEC and PAEP.
[32] In Portuguese: 'Institute Nacional de Propriedade Intelectual'
[33] However, Galina (2005) demonstrates, through patents requested to the United States Patent and Trademark Office (USPTO) by Brazilian subsidiaries (firms or inventors) from the sectors of telecommunication, informatics and electronics that the participation of these firms in the technological development of such industries has significantly low relevance, through results of activities carried out locally. Brazilian telecom and electronics industry is largely dominated by MNC´s and answers for a high share of R&D expenditures of the country industry.

It is important to note however, that empirical studies have identified subsidiaries in Brazil that accumulated relevant technological capabilities, some of which are relevant in the firm's global context, considering locally accumulated capabilities. Subsidiaries of MNCs in automotive (DIAS, 2003; CONSONI, 2004; CONSONI e QUADROS, 2006; DIAS e SALERNO, 2009; PEREIRA, 2009 telecommunications equipment (GALINA *et al.*, 2005) and capital goods (in the segments of mechanical and electrical equipment, and electrical engines) (STRACHMAN e AVELLAR, 2008) sectors are examples highlighted by the literature either by (re)definition of technological mandates by the groups they belong to, or by introduction or expansion of technological activities previously carried out by these subsidiaries. On the other hand, it appears that in certain sectors largely dominated by MNCs in Brazil, such as the pharmaceutical industry, the efforts of local R&D are very limited, essentially comprising development activities related to clinical trials (CAMILLO *et al.*, 2008; PARANHOS e HASENCLEVER, 2009).

Considering this paper's aims, it is important to note that there are few studies investigating the cooperation between subsidiaries of MNCs operating in Brazil and national universities/PRIs. Thus, it is important to highlight that in general, productive firms from Brazil cooperate very little, particularly with universities and PRIs, unlike what happens with firms from more advanced countries (CASSIOLATO *et al.*, 2005). These authors suggest that these partnerships are extremely limited even in the case of Brazilian firms that innovate and differentiate their products, which represent the most dynamic firms. Albuquerque *et al.* (2005), based on data from PINTEC 2000, demonstrate that the involvement of a firm with R&D activities (both internal and/or external) enhances the importance of universities as sources of information for its innovative activities. Quadros *et al.* (2001) and Queiroz e Carvalho (2005) put forward a convergent argument by suggesting that the weakness of the relationship between Brazilian industrial firms and universities/other research institutions is largely determined by the low degree of formalization of R&D activities in these firms[34].

Among the literature specifically focused on the cooperation of subsidiaries of MNCs in Brazil with universities and PRIs, Araujo (2005) identified, in the data from PINTEC's 2000 edition, a smaller percentage of NCs, in relation to MNCs in Brazil, that used some sort of cooperation with universities and PRIs focused on innovation. In addition to that, important innovation partners of MNCs are, in the following order: a) another firm of the group located abroad, probably the parent company or the subsidiary in a country with advanced NSI, and b) clients and consumers situated in Brazil. According to the author, this may point that MNCs probably develop products or processes more focused on adapting to local conditions. On the other hand, the study of Costa e Queiroz (2002) based on data from PAEP 1996, found no significant differences between subsidiaries of MNCs and NCs with regards to their accumulated technological capabilities of monitoring and interacting with other local actors, particularly with the science and technology (S&T) system. This perspective converges with the study by Ruiz and Bahwan (2010), based on data from PINTEC 2003, that examined the learning process resulting from; the firm's interaction with the outside world, the relationships between suppliers and users in the supply chain, the cooperation ('learning by interacting'), and the S&T advances through the outsourcing of research activities from other firms or universities/PRIs ('learning by hiring') by MNCs and NCs.. The authors found very small differences between these two types of firms within each sector of economic activitity, prevailing sectoral imperatives in the definition of learning processes.

[34] Erber (2010) presents a detailed review on the various studies on innovation in the Brazilian industry, beginning from the 1990´s.These studies show the low dynamism of the industry.

Camillo *et al.* (2008), in turn, present evidence of various subsidiaries that do not carry out continuous nor formal R&D activities in the country, and that sporatically work with Brazilian universities and PRIs for the provision of technological services related to; the local adaptation of product or process, and the specific development(s)/purpose(s) demanded by the market. According to the authors, the absence of long term ties with Brazilian universities and PRIs is a common situation among subsidiaries that focus purely on technological development activities in the country. In addition to that, this absence can be seen in firms that make continuous development efforts and sporadic research efforts.

5.3 METHODOLOGY

5.3.1 Survey of Firms

This paper will present the results of part of a survey carried out with firms, research institutions and R&D departments located in Brazil for an analysis of the technological dimension of the country. In this survey, a questionnaire was sent to each of the 1,622 firms in Brazil that interacted with national universities/PRIs, according to information gathered by the 2004 Census of the Research Groups Directory (DGP) from the National Council for Scientific and Technological Development **(**CNPq**)**[35]. In this regard, this study carried out an investigation of Brazilian research groups registered in the DGP, whose leader declared, in the previously mentioned Census, some sort of relationship with the production sector. In accordance with the methodology proposed by Rapini (2004), the interactions of research groups from CNPq Directory can be perceived as a proxy for interaction between firms and universities. Thus, the firms mentioned by the leaders of research groups were the core of this investigation.

The questionnaire took place from April 13, 2009 to November 30 of that year, totalling up 319 questionnaires, representing 18.9% of the total sent. These questionnaires were available online and were answered by the person in charge of R&D activities and/or of the interactions with universities and PRIs in the firms situated in the country.

The questionnaire comprises 22 questions divided into five blocks. The first one consists of six questions related to innovative R&D activities of the firm. The second one contains seven questions related to sources of information and knowledge, which the firm relied on to carry out its innovation projects. The third block, composed of only one question, refers to the importance given by firms to the contribution of universities or PRIs in their research activities, in accordance with the areas of knowledge. The fourth one, in turn, focuses on the firm's collaboration with universities/PRIs and consists of six questions. Finally, the fifth and final block covers only two questions related to the functions assigned to the university by the firm.

Only five of the 22 questions in the questionnaire will be analyzed in this paper. These five questions are: question 1, related to innovative and R&D activities of firms; questions 11 and 12, referring to external sources of information and knowledge used for innovative activities of firms; question 15, related to the reasons for the collaboration with universities/PRIs; and question 17, concerning the evaluation done by firms with collaborative projects with universities/PRIs.

[35] In Portuguese: 'Diretório dos Grupos de Pesquisa do Conselho Nacional de Desenvolvimento Científico e Tecnológico`.

In the analysis described in section 4 of this paper, the institutions that answered the questionnaire were classified as firms and other types of institutions, based on the legal status declared by them in Annual Relation of Social Information (RAIS) of the Brazilian Institute of Geography and Statistics (IBGE). In order to do so, the database that was built upon the survey was linked to RAIS database, through the Corporate Taxpayers' Registry (CNPJ) of the firm/institution. The institutions that were classified in RAIS as firms were all of those that both declared their legal status as "public firm" or "private firm" and did not belong to the following sectors: i) education; ii) associative activities and; iii) public administration. In this way, only 251 of the 319 questionnaires were classified as firms. The information related to these firms was, in turn, matched with the Central Bank's Foreign Capital Census which allowed us to identify whether the origin of the firm's capital was foreign or domestic. Thus, this research database includes 32 MNCs which corresponds to 12.8% of the sample.

5.3.2 The Multiple Correspondence Analysis Method (MCA)

The Multiple Correspondence Analysis (MCA) is a multivariate statistical method that allows the verification of association between more than two categorical variables. The main objective of this technique is to transform the qualitative information available in a table into a chart as a mean to facilitate data analysis (GRENACRE, 1994). The display of categories related to variables observed in a correspondence chart allows an analysis of the association to determined profiles, which sample's observations can be divided into. The analysis of these observations, described by a set of variables and their categories, will occur through the reduction of this system's dimension so that information can be systematized in a simplified plot (GRENACRE, 1994).

The method starts from an indicative matrix based on the data set that has the same number of rows as observations and the same number of columns as the categories of all variables observed. This matrix comprises values equal to zero, suggesting that the individual in question does not belong to a particular category for the correspondent variable, and values equal to one, suggesting the opposite. In that sense, each row of the indicative matrix is composed of a sequency of values zero and one, according to the characteristics of the individual it represents.

Based on this data, the main coordinates related to the rows and columns of the matrix wherein the data originates are calculated for each category of the evaluated variables. These coordinates will be obtained from linear combinations of original variables. These combinations, in turn, are responsible for the synthesis of information that can be found in the variable set into fewer dimensions (CAVALCANTE, 2006).

The criterion for comparison between any two categories, j and k, for the set of variables observed, is given by the chi-square distance, defined by d2j,k = n[(nj - nj,k / nj,k) + (nk - nj,k / njnk)], being nj,k a gross frequency of those individuals that have both categories j and k. The term nj represents the gross frequency of individuals that have only category j and nk represents the gross frequency of individuals that have only category k (RODRIGUES e SIMÕES, 2004).

Given this set of informations, the coordinates of each category are displayed in a correspondence chart that shows the new dimensions created for the analysis, considering its association as defined by the chi-square distance between them (CAVALCANTE, 2006; RODRIGUES e SIMÕES, 2004). The proximity between the categories analysed in the correspondence chart will determine the association between them. This association is used as a basis for the identification of profiles in which sample elements fit. On the other hand, if a variable is far from, it indicates the lack of

association between them. Therefore, the proximity of variables, or lack thereof, is used as a parameter to define profiles in which it is possible to fit the elements of the sample.

For the present MCA exercise, it was used the database obtained from the previously mentioned survey. More specifically, this study will analyze the information obtained from questions 11 and 15 of the questionnaire. The first question relates to the main sources of information used by firms in order to gain access to the knowledge produced in universities. Question 15, in turn, tries to capture from participants what the main reasons for interacting with universities are.

In order to use MCA, each of these variables from the survey questions has one of the following values: zero, if the firm attaches little or no importance to the item in question or one, if the firm considers such item as moderately important or important. Accordingly, each of the options in the two questions analyzed led to a categorical variable with value zero or one.

Besides the variables derived from questions 11 and 15 of the questionnaire, a categorical variable indicating the origin of the firm's capital was introduced in the analysis. This variable indicates value zero if the firm in question is national (NC) and value one if it is multinational (MNC).

5.4 ANALYSIS OF RESULTS

5.4.1 Descriptive Analysis of Survey Data

This section will analyze some of the main characteristics of the cooperation processes between universities/PRIs and firms in Brazil, differenciating the latter in NCs and MNCs, from the information in the survey of firms previously described.

The first topic of analysis is the introduction of product or process innovation by the firms that responded the survey and were involved in research activities with universities and PRIs. In table 5.1, it is possible to verify that 92.43% of surveyed firms (or 92.23% of NCs and 93.75% of MNCs) introduced product innovations in the last 3 years and 94.02% (or 93.15% of NCs and 100% of MNCs) introduced process innovations. The data suggests the existence of an association between the companies´ interaction with the national scientific infrastructure and innovation in the surveyed firms. In other words, firms that have projects with universities and PRIs are innovative. It is also noticeable the fact that all surveyed MNCs carried out some type of innovation in the last three years, which could suggest a commitment of these firms with this type of activity.

Table 5.1: Firms that declared the introduction any innovation in the last 3 years. Brazil, 2009.

Products	National Corporation	Multinational Corporation
Without innovation	17	2
With Innovation	202	30
Processes	National Corporation	Multinational Corporation

Without innovation	15	0
With Innovation	204	32

Source: Field Research. Br *Survey 2009*
Notes: Firms could choose more than one alternative.

From a total of 251 firms.

The second research topic relates to the importance attached by firms to universities and PRIs in the development of their innovative activities. The data on table 5.2 does not show significant differences between the importance given by NCs and MNCs to information coming from these institutions, considering that the percentage of greater importance attached to the sources of information did not differ much between the options. However, there are two exceptions regarding greater importance attached to the sources of information linked to universities; recruitment of personnel with an undergraduate or graduate degrees and the informal exchange of information by NCs, and research commissioned from universities and PRIs and carried out together with MNCs.

The MNCs' search for complementary research is gaining greater evidence when considering the importance of sources of information from PRIs. In table 5.2, it is possible to identify that the most important sources of information according to MNCs are joint researches commissioned from PRIs, as for NCs, publications and public conferences are the most important ones.

Another equally relevant aspect relates to the difference in importance of informal exchanges of information for NCs and MNCs. The former considers exchanges of information much more important than the latter, either when the source comes from universities or PRIs.

Table 5.2. Importance of Sources of Information from Universities and Public Research Institutes in the Innovative Activities of Firms. Brazil, 2009.

Sources of Information/ Importance of the source of information	Universities		Public research institutes	
	Moderately or very important (NCs)*	Moderately or very important (MNCs)**	Moderately or very important (NCs)*	Moderately or very important (MNCs)**
Patents	35.2	37.5	37.6	43.8
Publications and reports	72.1	71.9	61.9	56.3
Public conferences and meetings	63.0	62.5	58.3	56.3
Informal exchange of information	66.7	53.1	57.3	43.8
Employment of personnel with undergraduate or graduate degrees	67.1	56.3	49.5	50.0
Licensed technology	33.8	31.3	34.4	34.4
Consultancy with individual researchers	50.7	56.3	43.6	46.9
Research commissioned from the university	52.5	62.5	51.8	59.4
Research conducted along with the university	67.1	75.0	56.9	68.8
Participation in networks involving the university	51.1	46.9	46.3	43.8
Temporary personnel exchange	37.0	28.1	30.7	28.1
Incubators	22.8	28.1	21.6	28.1
Science and technology parks	36.5	40.6	32.6	37.5
The firm belongs to the university	14.6	15.6	21.1	18.8
The firm is a *spin-off* of the university	16.0	18.8	15.6	15.6

Source: Field Research. BR Survey 2009

* Based on 218 responses - one firm did not answer

** Based on 32 responses

Regarding the sources of information of universities and PRIs as a whole, it is important to highlight that, when a greater emphasis is given to their publications, reports and conferences, NCs pursue knowledge transfer through means that do not require higher transference costs, that is, that do not demand higher investments in the acquisition of knowledge for innovation purposes. The importance attached by MNCs to their own research projects as a source of information has a different context than the latter because these firms usually interact with universities or PRIs for isolated and/or complementary collaborations. These arguments are reinforced by the data in table 5.3, which presents the reasons for the collaboration of NCs and MNCs with universities and PRIs.

Table 5.3: Reasons for firms´ collaborations with universities and/or PRI´S. Brazil, 2009.

Reasons for collaboration/Importance	Moderately or very important (NCs in %)	Moderately or very important (MNCs in %)
Technology transfer from the University	64.38	37.50
Seeking technological advice or consultancy with researchers and/or professors for the solution of problems related to production	61.64	59.38
Increasing firm's ability to find and absorb technological information	58.90	53.13
Obtaining information about engineers or scientists and/or R&D trends in scientific areas	49.77	31.25
Outsourcing complementary researches, necessary for innovative activities within the firm, at universities and research laboratories, institutes, or centers	60.27	53.13
Outsourcing researches that the firm cannot conduct	57.53	68.75
Early contact with top university students for future recruitment	39.73	21.88
Using resources available in universities and research laboratories	63.93	56.25
Conducting necessary tests for products and processes of the firm	65.30	65.63
Getting assistance in quality control	30.14	25.00

Fonte: Field Research. BR *Survey*.

Note: One firm did not answer the question. 219 firms were considered national and 32 were considered multinacional.

In table 5.3, it is possible to see the specific and complementary objectives of interaction between MNCs and these institutions when they attach more importance to the reasons focused on finding isolated solutions for the firms' production, namely outsourcing researches that the firm cannot develop and carrying out tests for the products and processes of the firm. Regarding NCs, the attachment of greater importance to the execution of tests, followed by technology transfer and the use of infrastructure resources may suggest that there is a greater interest in the absorption and utilization of external knowledge, considering these firms might find it harder to generate new technologies, or even to invest in these procedures.

Finnaly, this study analyzes the achievements of firms' objectives in their collaboration with universities and PRIs. The evaluation of interactions that took place so far is very positive according to both NCs and MNCs, as shown in table 5.4. This success can be very relevant to encourage the increase in relationships between PRIs and research groups from universities and firms in Brazil. Particularly, the good evaluation of MNCs' interaction with local universities and PRIs (86.67%) is positive, suggesting that the knowledge produced in science centers in the country meets the demands of firms with international quality standards.

Table 5.4: Evaluation of Success in the firms´ collaboration with universities and/or PRI´s. Brazil, 2009.

Did the collaboration reach its objectives?	Number of answers* (NCs)	Number of answers* (MNCs)
Yes, the collaboration is/has been successful	182	26
No, the collaboration is not/ has not been successful	20	3

Fonte: Field Research. BR Survey.

*20 firms did not answer the question.

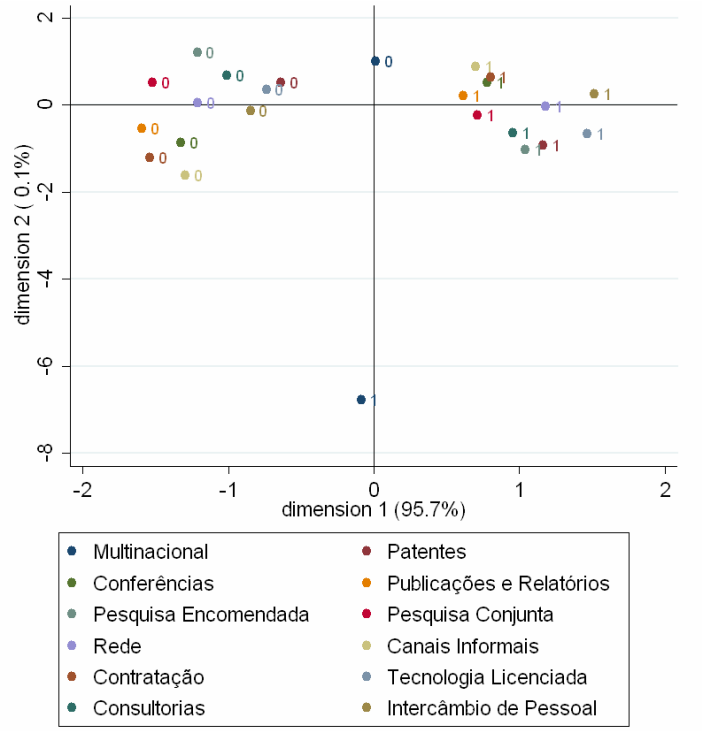
Note: From a total of 251 firms.

5.4.2 Patterns of University-Firms Interaction for NCs and MNCs in the Light of the Multiple Correspondence Analysis Method (MCA)

The Multiple Correspondence Analysis (MCA) method is applied in this work aiming at verifying the existence of, or lack thereof, distinct patterns of university-firms interaction for NCs and MNCs, as a means of complementing the information obtained by the descriptive analysis previously presented. In an attempt to identify these patterns of interaction, this study analyzed the main means used by surveyed firms to obtain scientific knowledge and information from the university system and the main reasons for this collaboration.

Chart 5.1 below shows the results obtained for the MCA considering the sources of information used by firms involving universities. This analysis considered the following sources of information: patents and scientific publications, commissioned research, joint research, participation of firm in networks involving universities, the use of informal means for obtaining information, the employment of personnel with undergraduate or graduate degrees, the use of licensed technologies, consultancy and personnel exchange.

CHART 5.1: Multiple Correspondence Analysis (MCA) as the Means used by Firms to Obtain Information from the University System in Brazil



SOURCE: Brazil *Survey 2009*. Authors' elaboration

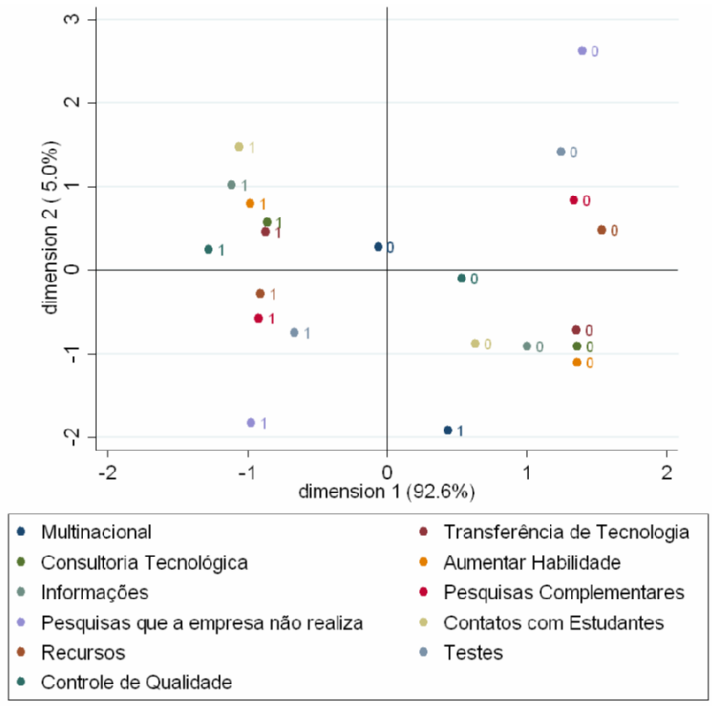
On the correspondence chart it is possible to see two well-defined clouds in dimension 1. The one in the positive area of this dimension consists of categories indicating the use of sources of information by firms. In the negative area of the axis representing this dimension, it is noticeable the presence of categories that point to the lack of use these sources. In the first quadrant, it is possible to highlight a profile of interaction associated with the pursuit of information by indirect means such as the employment or exchange of personnel, conferences and reports and publications. The fourth quadrant presents a profile focused on the direct pursuit of information at universities through, for instance, commissioned joint research, consultancy provided by the universities to firms, the use of licensed technologies and patents. The other two quadrants, on the other hand, are characterized by categories suggesting the lack of means of interaction considered here.

Although it is possible to distinguish two profiles of interaction based on sources of information used by firms, it is hard to observe their association with a specific type of firm, NC or MNC. The variable indicating the origin of the firm's capital shows its two categories (0=NCs and 1=MNCs) very close to the vertical axis of the correspondence chart but also scattered from the other

variables. This result for the exercise of MCA shows that, the issue of a firm in the sample, multinational or not, does not influence the type of information source used for obtaining information from universities, according to the sample's data observed. In that way, the origin of the firm's capital in the sample is not decisive for the differentiation of patterns of interaction with universities, based on the use of different sources of information.

Chart 5.2 presents MCA results in order to assess the reasons for interaction of firms observed in the sample. This exercise considered the following reasons for interaction: the pursuit for technical advice, information and technology transfer, rise in firm's capabilities, implementation of complementary research or research that the firm is unable to conduct, establishing of contact with students, use of available resources in universities, and testing and quality controls.

CHART 5.2: Multiple Correspondence Analysis (MCA) on the Reasons for University-Firms Interaction in Brazil



SOURCE: Brazil *Survey 2009*. Authors' elaboration.

As it has been shown, this exercise allows the possibility of identification of some associations among the categories of variables studied. Accordingly, the third quadrant shows the following reasons for interaction as believed by firms: the association between the use of resources in universities' laboratories, the testing of products and processes, and the outsourcing of complementary research for the firm's activities. Thus, one can define a profile with these categories as being characterized by the university's performance in filling the gap noticed in the productive sector through its physical infrastructure and human capital.

In the second quadrant, a profile that is characterized by firms that consider technology transfer, the pursuit of consultancy, the possibility of increasing firm's capabilities, the assistance in quality

control, the obtention of information, and the contact with students as the main reasons for interaction. This profile is characterized by the quest for qualification of the firm and isolated assistance as a justification for the interaction. On the other hand, variables distributed in the first and fourth quadrants show categories that indicate that the variables in question are not considered by firms as important reasons for interaction.

Somewhat similar to what could be observed in the previous exercise; the origin of the firm's capital is not associated with a specific profile of reasons for cooperation. Thus, one can verify that the category indicating the origin of the firm's national capital, for the variable "Multinational/Non-multinational" is again closely associated with the vertical axis of the correspondence chart, also demonstrating a lack of association toward some other variable among those observed. The category "Multinational" is also found scattered and near the horizontal axis in the correspondence chart. Its display shows that it is not associated with any of the other variables analyzed. Therefore, it is clear that, even with two distinct profiles on the reasons for interaction between universities and firms, it is not possible to distinguish them based on the analyzed firms' capital origin.

5.5 CONCLUDING REMARKS

The literature indicates a trend towards increased R&D internationalization within MNCs. This trend should lead to an expansion of the interactions between those firms and members of peripheral economies' NSIs in innovative processes. Thus, this study aimed at evaluating patterns of interaction between universities/PRIs and firms, focusing on the differences between domestic and foreign firms.

The evidence reported in the literature on technological activities developed by subsidiaries of MNCs in Brazil indicates that, although these firms account for a significant proportion of the technological effort of firms operating in the country, they cooperate little with universities and PRIs, similar to NCs. Moreover, the literature also suggests the predominance of sporadic interactions between MNCs and Brazilian universities and PRIs, focused on the provision of technological services and specific developments. It could be argued that they constitute "partial connections" between the scientific infrastructure and technological activities of MNCs, as emphasized by the literature that investigates university-firms interactions in Brazil.

The descriptive analysis of the data showed that although there are some differences in patterns of cooperation of NCs and MNCs, the interactions of these firms and universities/PRIs are usually quite similar. The main difference found is related to the reasons for collaboration. Emphasis is given to the fact that MNCs give more importance to the outsourcing research from universities/PRIs, while NCs attaches greater importance to technology transfer from universities/PRIs and the use of available resources in these institutions.

The data also suggest that the cooperation between MNCs and universities/PRIs could be characterized by the pursuit of meeting a firm's specific and isolated demand with regard to developing and improving its products and processes. NCs, on the other hand, attach greater importance to factors that may be related to the direct learning coming from the cooperation, such as technology transfer from universities/PRIs and the use of available resources in these institutions. Despite these differences, it was clear that the importance attached by NCs and MNCs to; the information from universities and PRIs, the profile of the company being innovative, the degree of

satisfaction and the degree of importance given to the reasons for cooperation, are very similar for both types of firms.

Additionally, the use of the Multiple Correspondence Analysis method suggested that it is not possible to distinguish patterns of interaction between universities and firms based on the origin of their capital, for the variables analyzed in this study. This evidence points out that whether the firm is a multinational or not, it is not one of the main determinants for them to establish different ways of relating to the university system in the country. Therefore, it becomes clear that NCs and MNCs behave quite similarly regarding cooperations with Brazilian universities.

Thus, according to the descriptive analysis and the multiple correspondence analysis, it was not possible to notice large differences in interactive patterns of NCs and MNCs with Brazilian universities and PRIs. It becomes evident then, that the origin of capital is not a determining factor for the differentiation of patterns of interaction between universities and PRIs with firms in peripheral innovation systems. This can be explained by the lack of effective R&D efforts in the country both by local and foreign firms. From this perspective, an additional contribution to studies in this field of research would be to introduce a sectoral perspective in the analysis, which could provide a better view of the differences in the interaction patterns of MNCs and NCs with the national scientific infrastructure.

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CHAPTER 6: CASE STUDIES: R&D DEPARTMENTS IN SOUTH AFRICAN AND BRAZILIAN SUBSIDIARIES

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6.1 INTRODUCTION

Two cases are presented here, to investigate the nature of the participation of foreign R&D in local knowledge networks in type 4 interactions. The cases, an agroprocessing TNC and its subsidiaries in South Africa, and an automotive TNC and its subsidiaries in Brazil, are described in a preliminary fashion. Further analysis will be undertaken to align more systematically with the tentative framework.

6.2 SOUTH AFRICA: TRANSNATIONALS IN THE AGRO-FOOD SECTOR

This case study report focuses on the role universities play in global innovation networks in the agro-food processing sector in South Africa. The emergence of global innovation networks in Asia, particularly China and India, is increasingly a subject of research, but their presence in other emerging countries like South Africa has not been investigated. The primary purpose of a global innovation network is for multi-national corporations (MNCs) to access innovation and R&D skills and capabilities that complement their own core knowledge competences, from other countries at lower cost (Ernst 2009). The research on which the report is based consists primarily of exploratory qualitative case studies, and the vantage point is the universities in the national system of innovation of the emerging economy. The specific focus is on the local-global linkages of MNEs and their subsidiaries in the dairy sub-sector with universities, public and private research institutes. Are MNEs locating their R&D and innovation activities in South Africa, and how are such decisions influenced by the capabilities of local universities and research institutes and by the competitive strategies of firms? If there is interaction with local universities in these global innovation networks, what forms does it take? How knowledge intensive are the channels of interaction within different forms of global innovation network, and how does learning and technology transfer to the benefit of South African universities take place?

The report is based on qualitative case studies conducted between May and September 2010. Cases were selected by a variety of means, both structured and serendipitous. The starting point was a scan of agro-food processing firms and an attempt to identify those who interact with universities. At the same time, a scan of universities was conducted in an attempt to identify those who interacted with multinational firms. Through this process, a decision was taken to focus on the dairy sector, as it appeared to yield a range of cases with varying degrees of university involvement.

Interviews were conducted with the R&D manager of the firms involved, as well as with local university partners where they were identifiable. R&D managers at other firms or suppliers involved in the networks were also interviewed. Background information on each firm, university and research institute member of the network was accessed via internet, trade papers and other documentary sources.

Trade papers, industrial research sources and policy reports were accessed to analyse the dynamics of the agro-food processing and dairy sectors in South Africa. Internet sources were accessed and interviews conducted to construct an understanding of the research capabilities with regard to agro-food and dairy science in South Africa.

The report also draws on a fresh analysis of the South African Innovation Survey 2005 dataset. A distinction was drawn between the innovation activities of local and foreign-owned firms, focused on collaboration with universities. This analysis was conducted for the entire set of firms as well as for agro-food processing firms specifically.

Section 6.2.1 of the report describes the context for the emergence of global innovation networks in the agro-processing sector, focusing on global competitive and innovation trends, as well as local capacity in relation to the dairy sector specifically. Section 6.2.2 uses Ernst's taxonomy to examine three cases in the dairy sub-sector, two characterized as intrafirm networks, and the third an instance of an emerging country firm constructing its own networks. Section 3 uses Arza's taxonomy to explore in detail the relationship between types of global innovation network and channels of interaction, to consider how the emerging country benefits in terms of knowledge transfer and local learning.

6.2.1 The Agro-food Processing Sector in Global and Local Context

Agro-food processing is typically characterized as a low technology sector with a supplier dominated mode of innovation, predominantly 'learning-by-doing' experimental up-scaling of food preparation processes. Major product brands have tended to change little, so that the scale of production is more important for competitiveness than technological change or innovation, as well as the ability to adapt dominant technological competences to a wider range of food product sources, for instance, from dairy products to chocolate or fruit drinks (Wilkinson 2002).

In recent decades, global processes of restructuring, driven by new patterns of food demand and the implications of biotechnology, have shifted the technology intensity and nature of innovation in the sector significantly, particularly for the leading food firms (Traill and Meulenberg 2002, Wilkinson 2002). The new content of demand meant two competitive trends for food processing MNCs. First, a further reduction of dependence on raw materials through the use of chemical alternatives, for example, nutriceuticals. This strategy has high competence barriers in terms of meeting regulatory standards and research. The second trend, improving preservation to move closer to the natural agricultural product as final food, means that food processing companies come into competition with food retailers who can link directly with agricultural production sources. The increasing use of biotechnology complicates these two options dramatically, and places global food firms under severe competitive pressure.

From the 1970s, changes in prosperity and consumption patterns meant that food firms had to shift to a more radical, multiple product innovation strategy, which entailed a diversification of core process technologies as well as of logistics, distribution and marketing, to suit rapidly changing and segmented markets. Product diversification and differentiation included expanding the range of products, shifting from individual products to prepared foods, or a new focus on cold and frozen snacks. A dynamic restructuring of the sector took place, with a new emphasis on product innovation and accompanied by process innovations in preservation technology, which means that the sector is no longer seen as low technology or supplier dependent. Nevertheless, the knowledge base of the sector was still relatively easily diffused and appropriated in developing countries.

As firms sought to reposition themselves, the 1980s saw a wave of international mergers and acquisition of firms whether in developed or developing countries, particularly newly industrializing countries, that resulted in expansion through market concentration. However, a parallel expansion by the large retail supermarkets once again increased the pressure on large food firms. Moreover, whereas initially it was possible simply to export mature products to new markets with low innovation costs, with the emphasis on rapidly changing markets, the demand for adaptation and monitoring of new markets increased.

The introduction of the new biotechnology paradigm and the shift in demand to focus on the functional content of food poses ever greater competitive challenges. A new link has been forged between food, nutrition and health, which impacts significantly on the nature of market demand – for fresh agricultural rather than industrialized products and organics, for example. The response is nutritional segmentation of products, but the speed of adoption of such (often minor) product innovations through the industry means that competitive advantage is short-lived, and requires expensive marketing. Another aspect is the development of new radical products with purported special health benefits, particularly functional foods or nutraceuticals. Functional foods have stimulated science-based radical innovation in the food industry, requiring expensive R&D, clinical trials, regulatory approval or patent protection. New innovation capable firms – including science-based start-ups, food ingredients firms and chemicals firms - are emerging and may become critical challengers to the large global firms in the food processing sector. The research into functional foods is converging with the application of advances in biotechnology in the food sector, reinforcing the need for differentiated products. In a related development, nutritional science has become critical to marketing the health image of some products that have health advantages. Hence, new marketing strategies, based on interaction with consumers to assess demand and preferences, is becoming more critical to competitive success, for example, focus groups and testing or new face-to-face sales.

In short, multi-national agro-food processing firms face significant competitive challenges in the form of market segmentation, short cycle product innovation and globalization, accompanied by a focus on nutrition and health foods and by the paradigm shifts made possible through biotechnology. Taken together, these mean that the global sector is increasingly shifting towards radical science-based product innovation, as well as marketing innovation. A number of global agro-food processing firms have a presence in South Africa – Nestle, Unilever, Danone, Parmalat, Heinz and Kellogg for example – and large firms in the South African sector in turn, have succeeded in entering global markets. The question is how these competitive dynamics shape the innovation strategies of global firms and their South African subsidiaries in the dairy sector. In what ways does the shift towards radical science-based product innovation drive these MNCs and their subsidiaries to interact and collaborate with South African universities and research institutes?

6.2.1.1. Innovation and agro-food processing firms in South Africa

On the surface, the agro-food sector based in South Africa appears to confirm the low technology, supplier driven, 'learning-by-doing' mode of innovation. Closer examination suggests a difference

between foreign owned firms, the multi-national agro-food processing companies that have subsidiaries and investments in South Africa, and domestically owned firms that have only begun to face global competitive pressures over the past fifteen years or so. Industrial policy planners argue that a major challenge to the local food industry is insufficient spending on R&D, particularly on new product development, so that firms do not move up the global value chain or equip themselves to enter global export markets (DTI 2007).

So, only 27% of the 434 domestically owned agro-processing firms participating in the national Innovation Survey 2005 claimed to be innovative, considerably fewer than the national average of 50% of domestic firms. In contrast, all 10 of the foreign-owned agro-processing firms reported that they are innovative.

The acquisition of new machinery, equipment or software accounts for 64% of agro-processing firms' innovation expenditure, while 30% is spent on internal R&D. A minimal 1% of innovation expenditure is allocated to external R&D, an indication of low levels of collaboration with other knowledge partners. Foreign owned firms spend approximately half of their innovation expenditure on internal R&D and another half on the acquisition of new machinery, with minimal expenditure on external R&D, less than half a million rand between all 10 firms. There is thus very little allocated to fund external R&D from universities and other public or private partners by both local and foreign owned agro-processing firms.

The main source of information for innovation activities for both domestic and foreign owned firms remains suppliers. Only 2% of the domestic firms cooperated with universities in South Africa, Asia and other countries, way below the national average of 16%. In contrast, 20% of the 10 foreign owned firms reported that they cooperated with universities in South Africa on their innovation activities.

The ways in which the new competitive trends driving greater science-based technological and marketing innovation are experienced by foreign and domestic owned agro-processing firms is thus likely to differ and be quite uneven, with older competitive dynamics continuing to drive some firms.

What of the dairy sector specifically? The global market for milk and milk products is growing. While South Africa has been a net importer of dairy products, exports have grown steadily over the past few years so that it is likely to become a net exporter, particularly to the African continent, and Southern Africa. Milk and milk powder accounted for 76% of South African dairy exports in 2008, rather than processed products such as cheese, yoghurts or drinks. As milk is highly perishable, production is technology intensive, and the industry is regulated by stringent local food safety and quality standards. Processing requires large financial investment in plant, for new product development and for marketing. R&D and innovation is considered essential to competitiveness, to keep pace with rapidly shifting consumer and industry trends, particularly new niche markets for functional foods and health-oriented products (Mahomedy 2008). At the same time, the local dairy sector stands accused of anti-competitive behaviour, in that the Competition Commission is pursuing a long running case of price fixing and market collusion against 8 milk producers.

Over the past decade, reflecting the trend to internationalization in order to secure better access to local and regional consumption markets, large global firms like Parmalat and Danone entered the South African dairy market, joining other long-established MNCs with powerful brands like, Nestle and Unilever. Like their global counterparts, the South African dairy industry is dominated by a few large national milk processors, and a large number of small locally based processors alongside a

group of producer-distributor firms. A foreign-owned subsidiary and three other large local firms dominate the milk processing market.

6.2.1.2 Agro-food in the South African science and technology system

Research capacity in agro-food processing in South Africa is concentrated in a small number of public institutions, and there is consensus that existing capacity has declined over the past decade (Lues and Lategan 2006). While biotechnology has received policy priority and a great deal of public funding in South Africa, much of the research activity focuses on agricultural biotechnology in relation to the primary sector, for instance, crop science (Kirsten and Gouse 2002, Pefile 2009, Gouse 2005). Two public research institutes have agro-food processing related programmes, one focused on agricultural research largely in relation to the primary sector, and the other on industrial research, where a food science and technology division (DTI 2006) has programmes on probiotics and nutraceuticals for instance (Pefile 2009). Five of 23 universities have food science departments, and two of these are strong research universities. Four others, mostly universities of technology, have food technology departments. Some universities also have biotechnology capacity that focuses on agro-food processing related research. Research focus areas are relatively heterogeneous and shaped by the local context, with emphasis on microbial population studies in relation to food spoilage, primary production and traditional foods, nutrition, new product development, biotechnology and fermentation and packaging and preservation (Lues and Lategan 2006). The capacity for developing highly skilled researchers and scientists at the universities is limited, and developing food science researchers at all levels is a challenge (Lues and Lategan 2006).

Two universities of technology have government sponsored food technology stations to support mainly incremental innovation in small, medium and micro enterprises, which have now been incorporated under a national technology innovation coordination agency. Their product development and testing services are also used by some large food firms. A number of private laboratories or niche research companies complement public provision, particularly in relation to testing and analysis for regulatory control alongside public standards testing laboratories, but also, for outsourced new product development. Entrepreneurs have identified a gap and niche in the market for applied research services, where firms are prepared to pay for solutions in the face of declining resources for internal R&D and the decline of research capacity in public research institutes.

There was traditionally a strong basis for research into dairy science in South Africa, but this has been scaled down and is now very limited in only two or three universities, the work at agricultural colleges has diminished and the public research institute responsible for agricultural R&D has funding, staffing capacity and management problems. In short, agro-food processing is not a major field of research strength in the South African national system of innovation, nor is there a large pool of highly skilled knowledge workers, one of the major drivers of global innovation networks. The emergence of global innovation networks attracted or driven by the capabilities of local universities and public research institutes at lower cost is thus not very likely in the dairy sector in South Africa.

6.2.1.3 The context of emergence

The context is thus one of new competitive trends driving agro-food processing firms to more radical science based innovation, but of limited innovation capacity in South African agro-food processing firms and of limited agro-food related research and human resource capacity in local universities, particularly in dairy science. The next section uses three case studies to examine what types of global innovation networks are emerging in this context, if at all, and in what ways universities and local public research institutes play a role in these networks. Two cases are MNC subsidiaries operating in South Africa. The one will be called Multidairy, in that it has multiple dairy products, and the other will be called Monodairy, in that it has a more focused range of fermented dairy products. The third case is a local supplier of a new environmentally friendly technology to the dairy industry, and will be called Newtech.

6.2.2 What are the Emergent Types of Global Innovation Networks in Major Dairy MNCs Based in South Africa?

Table 6.1 below provides an overview of key features of the three cases for comparative purposes.

Table 6.1 Features of the three cases

	Turnover	Locations	Product range	R&D / Innnovation arrangements
Multidairy	4Billion Euro (2009)	Global: locations in 16 countries	Milk, fermented products, cheese, fruit beverages	• Centre of Excellence in home country • Specialized Centers of Excellence in 2 advanced countries • R&D units in emerging countries
Monodairy	14 Billion Euro (2009)	Global: locations in 6 supranational regions with 159 plants (15 in Africa and Middle East region)	Fermented products and fruit beverages	• Centres of Excellence in home country • R&D units integrated into business divisions • Specialised transversal scientific research units • R&D units in emerging country subsidiaries • Structured communication network and collaboration between local and central teams
Newtech	Not available	• Local • Global: locations in Europe • (Potential) customers in US, Europe and Australia	Technology as alternative to heat pasteurisation	• Internal technical team • External Research Committee in home country • Collaborative partners in • adva nced countries

6.2.2.1 Global internalized technology transfer and local adaptive R&D: the case of Multidairy

The case of Multidairy is typical of other MNCs active in the South African dairy sector. Innovation centres are located in firm headquarters in the home country or there is off-shoring to other key locations in developed countries, but very limited off-shoring to emerging countries (Ernst and Hart 2008). The MNC does not outsource R&D or collaborate extensively with firms or universities outside the company, particularly in emerging countries. In terms of Ernst's taxonomy, it is a case of an intrafirm network that offshores limited aspects of innovation to its South African subsidiary (Ernst 2009). That is, Multidairy represents an instance of global internalized technology transfer, coupled with local adaptive R&D.

Multidairy is a large multinational European company and one of the major players worldwide in the production and distribution of milk, dairy products and fruit-based beverages. In 2009 it generated revenue of 4 billion Euro and employed about 14 000 people in 16 core countries with offices and manufacturing facilities in Europe, the Americas, Africa and Australia. Using South Africa as a springboard, the company is expanding its reach in the African continent, with manufacturing, sales and marketing operations in Mozambique, Swaziland and Zambia, and a sales and marketing operation in Botswana.

Multidairy SA, a fully-owned subsidiary, is the second-largest player in the South African dairy processing market, having broken into the market in the late 1990s, and now employing around 1 600 people. Multidairy SA group contributed almost 8% towards Multidairy revenue in 2009, an increase from 2007 and 2008.

The group competitive strategy has been to concentrate the product portfolio on milk and derivatives and fruit-based beverages, but particularly to focus on innovation and functional products with a high value add. The group has been in a position to innovate and acquire leading-edge production technologies aimed at competitive advantage in terms of price in their core businesses, including UHT milk and fruit beverages, particularly in relation to functional products. It claims parity to leader technologies in the production of yogurts, low-fat desserts and fresh functional cheeses.

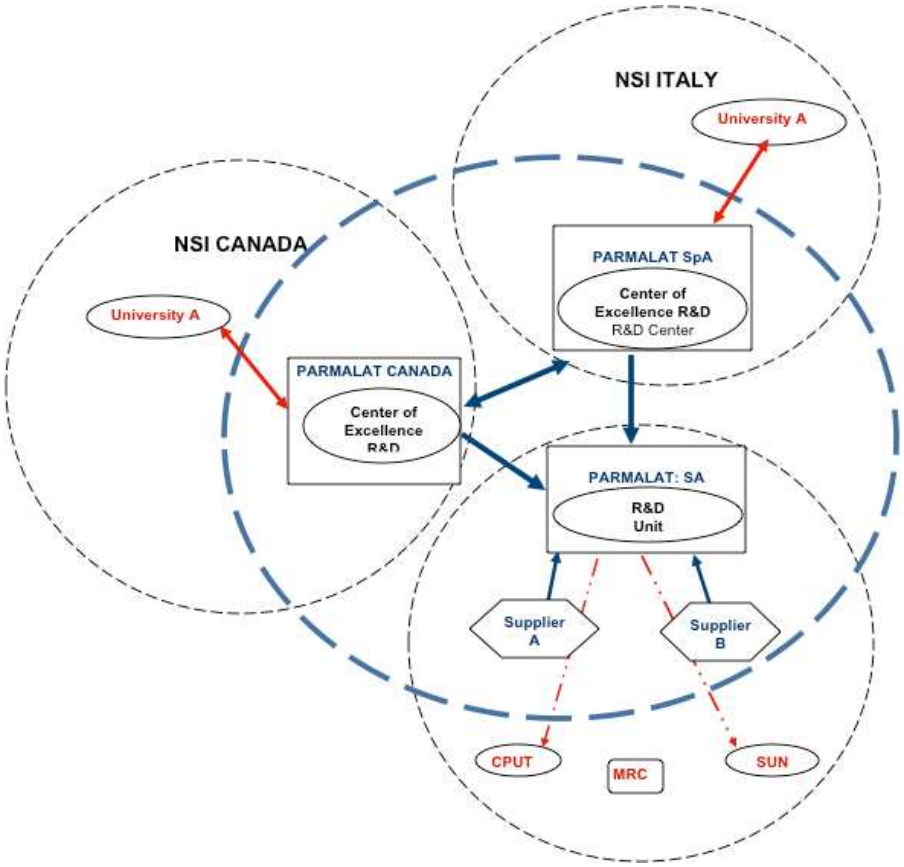
The group's innovation strategy is to leverage product and process innovation at the global level in individual countries, but with R&D activities coordinated and controlled centrally by the Centre of Excellence located in the parent company in Europe. The group R&D strategy is based on a strong rationalization of the number of new products developed locally through a process of centralized selection. It proposes to develop partnerships with universities and specialized institutes worldwide, but specifically, in the complementary fields of nutrition and well-being to inform in-house product development. In-house R&D activity focuses on the development of new functional products with high added value, and on development of production and packaging technologies with a high level of innovation to increase taste, quality and duration over time. There are other Centres of Excellence with specialised expertise, for example, in Canada (with up to 40 researchers) and in Australia that focus on specialized products. Such a Centre of Excellence has not been located in South Africa, and the local R&D operations are on a smaller scale. Other emerging countries like Venezuala also have a very small R&D team with 2 to 3 people, who operate as 'translators' of formulations sourced from the central R&D unit and converted to upscale manufacture. A similar trend is found in other agro-food processing MNCs in South Africa, for instance, a global player that has major research centres in the UK and Netherlands, and has established research centres for product innovation in India and China, but its South African operation remains a smaller scale

'technology development centre'. The range of R&D and innovation activities offshored to emerging countries is limited and at lower levels of novelty and complexity.

The R&D unit of Multidairy SA is the fourth largest in the global group, but it is very small, consisting of 6 people. This is nonetheless considered large in comparison with the average unit in the South African dairy industry. The unit works on a consultation basis with all the manufacturing plants in South Africa and other Southern African countries and is responsible for signing off all new product development in the region. The main focus of the R&D unit is applications development, rather than research on new technology or to develop cutting edge products. They 'combine ideas from different sources and bend them a bit to suit local purposes' (Interview, Multidairy SA). Most of the R&D work for new products is conducted within the group's Centres of Excellence. For example, a calcium enriched milk product was designed by Multidairy Australia, and the SA R&D unit adapted it to produce the new product in South African operating conditions. Multidairy SA thus represents a typical example of a subsidiary of an MNC adapting mature technologies for the local market and to suit local conditions. Such incremental innovation does not typically require science-based inputs.

Figure 6.1 illustrates the relationships between the MNC's R&D units and universities in the home, partner and host countries. The relationships within the Multidairy group tend to be one way, with the Centres of Excellence doing the cutting edge research, and R&D expertise typically sourced internally to the MNC. The SA subsidiary can take innovative products that have been successful within the parent company, and localize them and get to market more quickly and effectively than if it relied on R&D from universities or other external research partners. Internalisation of innovation has the added benefit of protection of intellectual property and proprietary knowledge. The SA R&D unit thus exchanges with the European Centre of Excellence on specific projects, for example, on the core corporate directive to develop functional foods. Such premium products are new to South Africa, and hence, there is a high level of market uncertainty. A range of functional food products was developed with the help of the Centre of Excellence in Europe.Ideas are also sourced from R&D intensive suppliers. Most of the local suppliers of flavourants and colourants or chemical compounds have international locations, mainly European with local agents or subsidiaries. A range of product options are developed and Multidairy selects and tailors these to suit the profile of their South African market. For instance, a supplier may develop a product with a new compound ingredient.

Figure 6.1. The structure and relationships of the Multidairy network



The R&D unit will put this into the Multidairy formulation and process parameters, and evaluate on a laboratory scale whether they will get the same results with their own materials, and what will be required for implementation at full production scale. The R&D unit may also do consumer research, to determine what preferred characteristics of different products are valued. In many cases the technology does not change, but the way the product is presented to consumers changes rapidly and differs. For instance, current trends are coffee flavoured yoghurts, or flavours based on indigenous plants such as aloe or other super fruits. With this kind of incremental innovation, Multidairy SA does not require universities' fundamental or applied R&D to a great extent. What they may need to outsource is market research, and routine testing and analysis.

Figure 6.1 illustrates that there are few linkages with local universities. The subsidiary R&D unit is in principle open to cooperation with local universities and there have been a number of attempts to collaborate, but to date, they have not had specific formal research-related interactions at all. The main reason, it is evident, relates to the group's competitive strategy and the incremental and adaptive nature of the innovation and R&D that the Multidairy structure offshores to the subsidiary. However, the lack of technological capacity and research infrastructure in local universities or local public and private R&D laboratories further drives reliance on internalized networks. Multidairy does not have the equipment to do a full nutritional analysis of new products and would generally outsource, preferably to a laboratory that does such work on a regular basis. To outsource testing to an external laboratory requires that they should be accredited, and have access to all the necessary

reagents, up-to-date methodologies and trained staff, which is not economical for most universities or private laboratories to maintain. For example, Multidairy proposed to contract out a full nutritional analysis for a new long shelf life milk, to test a new heat treatment technology, which their current plant laboratory test facilities could not measure. A university was approached but they were not sufficiently specialized with the equipment, facilities and technological skills required. Multidairy does not have the time to wait for the university to develop this expertise. The R&D unit decided rather to incur the expense of sending the samples to European headquarters with the knowledge that in 10 days, they would have reliable results that could be trusted. Control samples from the Centre of Excellence could be used, so that there were referenced results, which was an added advantage.

Moreover, university R&D is perceived to be high cost and high risk. There was a plan with the introduction of new functional products, to outsource clinical trials to a university and a public research institute, to confirm the health claims of the new ingredients. However, the amount quoted was viewed as too exhorbitant, partly because the risk was high, given that the market is not well established and potentially low volume in South Africa. The decision was thus rather to position the product for the general public to maintain healthy living, and Multidairy did not proceed with the clinical trials or research relationship with the university and public research institute.

In general, Multidairy represents the case of an intrafirm network that offshores a limited set of activities to South Africa. It is global in that innovation takes place in more than one location, and there are multiple linkages, but all are internalized to the MNC. Innovation conducted by the local R&D unit is incremental and driven primarily by the MNC or local subsidiaries of global suppliers. Technology transfer from the MNC centres is uni-directional and these centres exclusively conduct the radical science based innovation required for the group competitive strategy. R&D in the subsidiary largely consists of testing and analysis to adapt innovation and R&D from the centre to local market preferences and operating conditions. The network of firms is internal to the group, and the networks with universities are very weak, virtually non-existent and not actively pursued. Local universities lack the technological capabilities for the kinds of testing and analysis that the subsidiary would prefer to outsource. The small local market means that there is a high risk for cutting edge products so that the high costs of local university research is a barrier to interaction. This type of global innovation network seems typical in the South African agro-food sector.

6.2.2.2 Global internalised technology transfer and innovation to expand local markets: the case of Monodairy

The case of Monodairy mirrors that of Multidairy in many respects, in that it too, is a case of an intra-firm network that offshores aspects of innovation. Monodairy SA is a fully-owned subsidiary of Monodairy Group in Europe, focused on the manufacture of fermented dairy products and fruit beverages. Monodairy is far larger, and employs 80 000 people worldwide and operates in 6 supranational regions, generating revenue of 14 billion Euro in 2009. Monodairy's competitive strategy reflects cutting edge trends of the global agro-food sector, aiming to promote the nutritional and health benefits of its products, rooted in an environmentally friendly operation. In particular, its innovation strategy foregrounds the development of products with nutritional quality adapted to the profile and taste preferences of local populations.

Monodairy originally entered the South African market in the mid 1990s through a joint venture with a local dairy company in which each produced complementary sets of products. Recently the

MNC bought back the local company's stake and has expanded to Angola and Mozambique. Monodairy SA reported a turnover of approximately R2.1 billion and employs 380 people. In relation to its main product Monodairy has been a technological leader and has about 52% local market share. This declined over the past five years, in the face of competition from private dairies and retailers, who have invested increasingly in technology and expertise.

For new product development, like Multidairy, Monodairy SA draws on the global R&D resources of the group, particularly the research headquarters in Europe. The global R&D system is large, with approximately 1 200 researchers in 15 countries and a budget of 200 million Euros. The group R&D strategy links basic scientific research with clinical research and product development, drawing on disciplines as varied as nutrition, immunology, neurology, food safety, microbiology and consumer behaviour. The MNC holds a large patent portfolio. Unlike the strongly centralised uni-directional Multidairy model, Monodairy has organised its innovation activity in a hierarchical global network of R&D centres that has a greater degree of knowledge exchange. Figure 2 illustrates the partners and their relationships. The 'flagship' does control innovation, and more complex products are developed at two principal research centres in Europe, patented and rolled out globally. Some R&D units are integrated into the main business divisions and some are transversal, conducting scientific research related to the health and nutrition aspects of the products. Nevertheless, most major countries have a research unit with the capacity and mandate to conduct internal R&D and develop their own innovations, including emerging countries like South Africa. Monodairy SA thus has more scope for R&D, innovation and new product development than Multidairy SA. The research unit conducts research into flavours, nutrients, textures and recipes that are specifically tailored for the South African market, with any intellectual property becoming the property of the group.

There is a strong group commitment to a network organizational culture to facilitate communication between the centre and local teams with similar functions and responsibilities. The country units are connected to the main R&D centre in Europe through a structured communication network. There is an annual meeting to identify innovations that would be of interest for the entire group. The countries are also organised in zones which communicate internally so that potential new products developed in one country may be adopted in others. A new product developed in South Africa is now being rolled out by group subsidiaries based in other countries. County units also collaborate on R&D, to share expertise and resources. For Monodairy SA, the main partners are in Europe, the most advanced in terms of market sophistication and research capabilities, and Mexico is an emerging country partner. Significantly, R&D takes the form of both marketing research and product research. Figure 6.2 represents these relationships graphically.

The large scale, specialisation, easy access to Monodairy's global research capabilities and the in-house product development capability thus limits the need of the subsidiary to outsource and hence, to interact with local universities. However, Monodairy group prioritises scientific collaboration with universities and specialized private research institutes, primarily located in Europe and the USA. Unlike Multidairy, there have been limited research relationships between Monodairy SA and local universities, tapping complementary expertise in relation to packaging or nutritional analysis of target markets, for example. An example of these dynamics is a new vitamin enriched product developed specifically for those in the low income market segment in South Africa and other emerging countries. University researchers at a medical school were involved in nutritional mapping to identify key deficiencies among the population, to inform the parameters of the new product. A marketing and distribution innovation accompanied the product innovation, in the form of a novel micro-distribution system based in the townships and training unemployed women as

sales agents through informal outlets and door-to-door sales, rather than established retail chains. The product was developed by Monodairy SA R&D unit, to be sold at low cost, and also, so that it could be stored at room temperature for a period of time, to eliminate the challenges of maintaining the cold storage chain. The added advantage of the project was that it linked with Monodairy's broad-based black economic empowerment obligations and contributed potentially to employment creation and social development.

Monodairy thus represents the case of an intrafirm network that offshores a wider range of R&D activities to its South African subsidiary, but also, outsources a very limited range and scale of complementary activities to local universities. It is global in that the subsidiary research unit is inserted into a network that operates in multiple countries, but one that is hierarchically structured with innovation and research expertise remaining primarily concentrated in the MNC headquarter and other advanced countries, although allowing for innovation originating in the local subsidiaries to circulate through the group. In effect, a limited degree of product innovation is now offshored to the emerging countries, as the subsidiaries innovate technically improved products for local conditions that may attract wider markets and be taken up through the group. The network is not solely internalised to the MNC, as is the case with Multidairy, but the externalised network is not extensive nor is interaction with universities intensive (this will be explored further in Section 3).

6.2.2.3 A global-local knowledge intensive technology development network

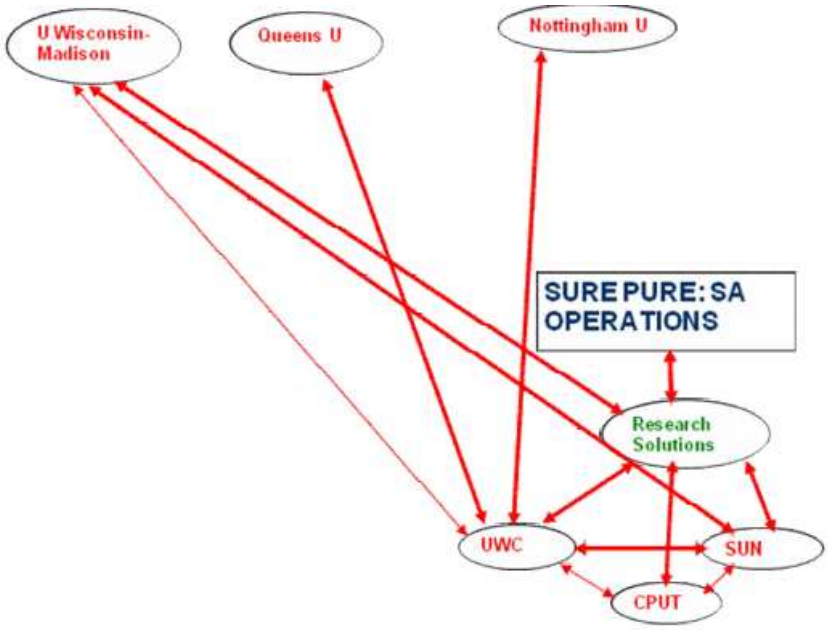
The third case differs completely in that the lead firm at the centre of the network is not a MNC based in the European Union or United States, but a South African firm constructing its own networks – the third type of global innovation network in Ernst's taxonomy. Many cases of new 'network flagships' (Ernst 2009) from Asia are successful large firms with complex networks of specialized suppliers and universities, some of which have established their own R&D centres close to global industry leaders and centres of excellence in developed countries. In contrast, Newtech is a local start-up firm (with part foreign ownership) attempting to prove the efficacy of a new to the world technology in order to access global dairy markets.

Newtech is a small South African start-up company that began operating commercially in the mid 2000s after 8 years of R&D. For statutory, financial and intellectual property protection reasons the shareholding changed and the head office was moved to Europe. The investment of venture capital on a significant scale into a research intensive enterprise is unusual in the South African context, unlike the trends in China or India (Ernst and Hart 2008). The innovative product is a purification system that is used as an alternative to heat pasteurization and preservation treatments. The patented technology is unique because it can be used to process turbid liquids like milk, wine or fruit juice, as well as industrial liquids, at low cost, with less energy and potential taste benefits. Current clients include firms manufacturing fruit beverages (where the green technology provides a competitive edge), wine (where it has local regulatory approval) and small organic dairy producers, particularly cheese makers. The dairy market has been targeted as particularly lucrative because of the constant daily volume of liquid requiring purification. Current dairy regulations globally require heat pasteurization, and until regulatory approval has been obtained and widescale commercialization is possible, some customers are using the technology alongside pasteurization to extend shelf life of milk products.

The fledgling research-driven company had an international patent registered in the US and Europe, and the goal to obtain regulatory approval, but there was very little research data to support

the product. Hence, the strategy for the first phase was to validate the technology in South Africa. Internal R&D infrastructure and capacity is too expensive for a small start-up firm. In terms of daily operations, the firm has a very small internal R&D capacity, mainly on the engineering side. The firm turned to external research partners, to local universities and their foreign collaborative partners, to conduct basic and applied research to prove the efficacy of the technology. Figure 3 illustrates the relatively simple network in the first phase, involving the firm, a private research company, two local universities and a number of international university partners.

Figure 6.2. Research relationships for Newtech phase 1

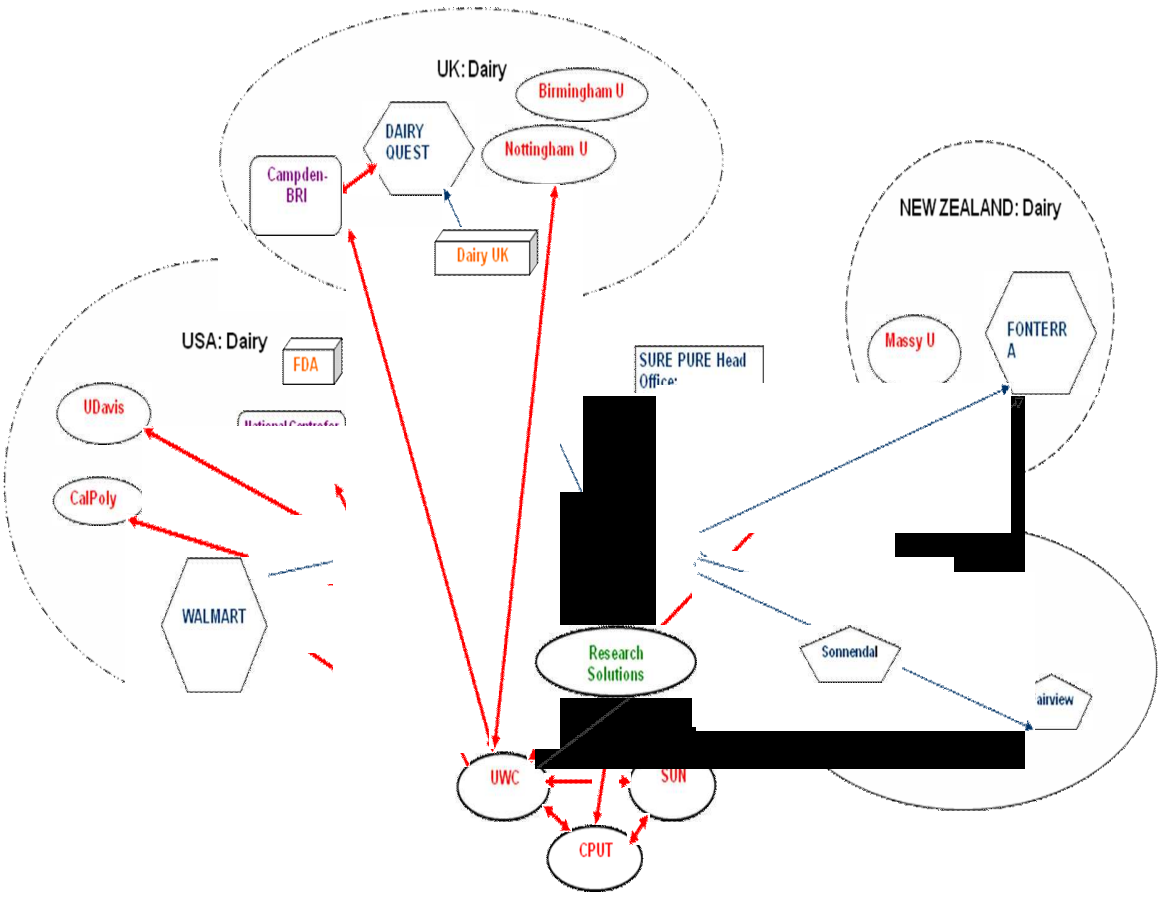


The local universities are in close proximity to one another, with the required expertise, expensive equipment and facilities available for independent validation. Each has complementary expertise in a range of disciplines, for instance, on the biochemical aspects, the food science aspects or the food microbiology aspects. Proximity was an advantage given that the core equipment is large, and not easily transportable for experimentation and the engineering adjustments required in the early phases. One reason that these specific universities were drawn in to the network was through personal networks. A significant individual plays a key intermediary role in the close collaboration between the firm (for which he worked in the early years), his own private research company, Privateresco, and the local university partners (where he was a post-graduate student). Privateresco is focused on new product development in the dairy industry, and on finished products sold to the consumer. It is essentially an intermediary technology transfer organization. An indication of its research and interactive capabilities is that a European MNC, a research-intensive global leader in food ingredients, enzymes and bio-based solutions, recently acquired Privateresco as part of a strategy to expand and complement existing business in the dairy sector in sub-Saharan Africa. This intermediary firm was able both to draw on the science and technology of the university and to understand industry needs, in order to facilitate the transition of theoretical knowledge in a form accessible to the firm.

At a later point, in the face of a lack of local research expertise in dairy science, the university scientists involved colleagues at an American university that has a very good reputation as a dairy university, and a UK university that has an excellent biohazard research facility that is not available locally. These foreign universities were drawn into the network to bring complementary cutting edge scientific expertise and to gain a more independent corroboration of critical aspects of the work.

The scientific proof required to enter global dairy markets took far more time than was anticipated, but the research required for proof of product is now largely completed and a basic level of competence has been reached. In the second phase of development, the firm has confidence to enter the global market and hence, the need to attain offshore accreditation is a key driver of collaboration with foreign universities. Figure 6.3 illustrates the more complex sets of networks in phase 2, as the firm conducts global applied research to validate the local results, in order to obtain regulatory approval and access global markets. Foreign regulatory authorities require research to be replicated in their own local institutions as part of the dossier for approval. There are two current sets of collaborations, one in the UK and the other in the USA.

Figure 6.3. Research relationships for Newtech network phase 2



In the USA, the focus is on attempts to gain FDA approval for the use of UV technology as an alternative to pasteurization, before it can be implemented commercially. The FDA reportedly has regard for the testing and analysis done in South Africa, but require their own independent collaboration. A university and a university of technology have been contracted as the main research partners, and one of the largest global food retailers is the main firm partner and potential customer. The universities have been selected for their expertise in dairy science, and the firm is interested in utilizing the technology to enhance the shelf life of their milk products. Independent results are key for Newtech, and the fact that the technology has been tested at these two universities with a high reputation in the dairy industry is a potential marketing tool.

In the UK, the work has a microbiological emphasis and collaboration is with the two universities as well as a coordinating dairy industry association. This body currently has a strategic focus on the environmental impact of dairy, on reducing the carbon footprint and energy inputs. An indication of the potential significance of the technology is reports that it was recognized as a 'most likely to succeed' technology for environmentally friendly, viable alternatives at the association's 2010 conference. However, there are there are a few rival technologies under consideration that may achieve the same objective – an alternative to heat pasteurization - such as microwave and pulsed electric field pasteurization, and novel cleaning systems such as ultrasonic cleaning and whirlwind and ice pigging. Commercial partners include one of the largest dairy firms in the UK that has a very good internal R&D unit, and works closely with a privatized research institution which has equivalent regulatory standing to the FDA.

The local universities' research networks were important in accessing the specific foreign university partners, selected on the basis that they are at the global forefront with a sound knowledge of the dairy sector and related matters. The foreign universities are believed to be more interested in the science than the financial benefit of collaboration, but nevertheless, their cost is very high, about two to three times that of the local universities. The two local university professors, together with the intermediary Privateresco and the Newtech technical team form a kind of research committee to lead the R&D network. At the moment there is no direct financial benefit for the external members of the research team, except for specific research contracts. For instance, one professor was involved in a large contract to test application of the technology for a large dairy firm in New Zealand. There is however a long term financial interest, and a commitment that should the technology becomes successful, the research team may be incentivized with shares in the company. Approval is proving to be a much longer process than envisaged, but the research team claim that they can anticipate the outcomes of the research conducted by the foreign universities, largely a verification of the results they have obtained through their own local research.

Newtech thus in effect outsources the R&D to local and foreign universities to substitute for internal research capacity. It does not offshore to foreign universities or firms to save costs, but rather, to access cutting edge technology and global centres of excellence. Newtech represents the case of a South African firm building its own global innovation networks. It is global in that R&D and innovation is dispersed across firms and universities in a number of countries. At its centre is a radical product innovation that has potential to make a major impact on the dairy industry, should its claims be borne out. It entails a strong applied research network to validate local R&D to satisfy global regulatory standards of approval, in order to enter new global markets. The South African firm directs and controls the innovation network, but relies strongly on the outsourced expertise of the local research partners. Such radical innovation requires substantial investment and is extremely high risk, particularly for latecomer firms in emerging countries (Ernst 2009).

6.2.2.4 Types of emergent global innovation networks in the dairy sector

This section categorised each case in terms of the type of global innovation network it represents, and focused on the illuminating the R&D and innovation related structure of the networks. Multidairy represents an instance of an intrafirm network with some offshoring to the emerging country subsidiary. Monodairy is an intrafirm network with offshoring to the emerging country subsidiary and very limited local outsourcing. Newtech is a contrast instance of an emerging country firm building its own global network.

The intrafirm case studies highlight that in the South African dairy sector interaction tends to occur primarily between firms, the MNC and its subsidiaries, but also suppliers and potential customers. The global shift towards radical science-based product innovation in the agro-food processing sector does not drive MNCs and their subsidiaries to interact and collaborate with local universities and research institutes on any significant scale. Rather, they outsource and interact extensively with high scientific reputation institutions in Europe and the US. Knowledge transfer within the group may disseminate the benefits to the local subsidiary, but does knowledge transfer extend beyond the firm to other institutions in the local innovation system? The South African firm on the other hand, collaborates and outsources R&D and innovation to local universities and their foreign partners. Knowledge exchange is more intensive and extends back into the university and scientific community. Different types of global innovation network thus have different types of relationships with local universities and research institutions. In turn, these have distinct implications for local learning and technology transfer in the emerging country. The following section will examine in greater depth the nature of the channels of interaction that do exist with local universities, and their associated benefits and risks, in these different types of global networks.

6.2.3 What are the Channels and Benefits of Interaction for Local Universities?

Table 6.2 below sums up the channels of interaction and the nature of network relations associated with each type of global innovation network.

Table 6.2 Channels and benefits of interaction for local universities

Firm	Type of GIN	Channels of interaction	Knowledge	Benefit: university	Benefit: NSI
Multidairy	Intrafirm with some offshoring	TRADITIONAL: • Skilled graduates/human resources • Informal exchange • Firm sponsorship of post-graduate bursaries	• Unidirectional • Informal • Indirect • Little knowledge exchange	Economic - very limited Intellectual - non existent	Little contribution to local knowledge intensification
Monodairy	Intrafirm with offshoring and very limited outsourcing	TRADITIONAL: • Skilled graduates/human resources • Sponsorship of post-graduates SERVICE: • Customized training for firm • Access to research facilities • Consultancy (target market related)	• Unidirectional • Formal • Direct • Not knowledge intensive • Some knowledge exchange	Economic - medium Intellectual – limited	Potential for developing local knowledge capabilities but exchange tends to operate in favour of MNC
Newtech	Emerging country building own network	TRADITIONAL: • Skilled graduates/human resources • Sponsorship of post-graduates • Sponsorship of research equipment SERVICE: • Access to research facilities and infrastructure • Consultancy (core technology) BI-DIRECTIONAL: • Researcher exchange • Contracts • Access to advanced facilities • R&D collaborations • Joint publications	• Bi-directional Formal • Direct • Knowledge intensive Knowledge exchange	Economic – individual and research group Intellectual - maximal	Opportunities for interactive learning and knowledge transfer high

6.2.3.1 Channels of interaction within an intrafirm network with limited offshoring

The Multidairy group research policy is to pursue partnerships with university and research institutes globally, but in relation to a specific complementary field – nutrition and wellbeing – rather than to the core product innovation. MultidairySA does not interact with local universities or public research institutes in any meaningful or direct way. The advantages of drawing on local university research for innovation to drive core competitive strategies typically did not outweigh the risks. Examples were cited of planned contract or collaborative research with universities, particularly in relation to proving the health related aspects of new or improved products. These plans were abandoned, either because of high costs of R&D in a limited local market, or because of perceived ethical or health risks.

There is evidence of traditional channels of interaction with local universities. An important point highlighted by one of the university professors is that the main channel of interaction between most MNCs and local universities is indirect - it relates to the supply of (lower cost) skilled graduates in science, engineering and technology fields to meet the human resource needs of MNCs and their subsidiaries. Universities may also play an important direct role in placement through accessing their student networks on behalf of firms.

Where there is direct interaction with local universities, it tended to be very limited, taking two forms: informal exchange between individuals, or sponsorship by Multidairy of university activities. For instance, they sponsored a Masters student at a research university to do a sensory analysis of cheese, and they support a university of technology by participating in the review of an annual new product development project within its Food Technology programme. There is evidence that the sponsorship channel is typical of many MNCs operating in the South African dairy

industry. Some are major sponsors of research chairs, specialized research institutes and student bursaries in local universities. This interaction is motivated by a philanthropic role related to its corporate social responsibility commitments, rather than by its competitive strategy. For the MNC there are potential brand or marketing benefits, but no contribution to the firm's innovation strategy.

The benefits of interaction for universities and the national system of innovation in the case of an intrafirm offshoring network like that of Multidairy, with primarily traditional channels of innovation, are limited. There are no intellectual benefits, and limited financial benefits for the university. There is a direct benefit from sponsorship channels, in terms of contributing to the infrastructure, research and human resources of the university, and to high level human resources in the national system of innovation. The scale of such contribution in the face of the decline in research capacity in food science is questionable. Interaction tends to be uni-directional in terms of knowledge exchange, with little knowledge intensity. There is little benefit in terms of direct technology transfer or developing new science and technology knowledge and capabilities within universities and public research institutes. We may expect that when the cognitive distance between the actors in a network is high, there will be less opportunities for interactive learning. Hence, there is little contribution to local knowledge intensification from this network.

6.2.3.2 Channels of interaction within an intrafirm network with offshoring and limited outsourcing

Monodairy, as an intrafirm offshoring network with limited outsourcing, equally benefits from the traditional indirect channels of the supply of skills, and from the direct but not knowledge intensive channels of sponsorship and informal networks. However, as part of its R&D strategy, Monodairy group highly values collaboration with universities and research institutes. It reports some 200 partnerships worldwide, which result in joint presentations at scientific conferences and scientific publications (50 were reported in 2009). Monodairy SA thus also has a wider range of service channels of interaction that involve a degree of direct knowledge exchange and are more formal. These include training and skills development, whereby staff attend customized management programmes at a university, for example. It may include collaboration around the use of specialized university equipment or facilities, for instance, a collaboration for the Monodairy R&D unit to use vacuum research facilities to optimize the properties of their packaging in order to accommodate changes in altitude. It may also include outsourced consultancy research, as in the example of the new product developed for a low income market segment described above, where universities conducted nutritional analysis of the target population to inform the parameters of the product. These channels involve knowledge exchange but largely uni-directional, in that the firm controls the knowledge resources in terms of its own research or skills strategies, and the benefit for the university is largely financial. Here there is the potential for technology transfer or developing new science and technology knowledge and capabilities but the flagship firm firmly controls the process, and knowledge exchange tends to operate in its favour.

6.2.3.3 Channels of interaction within a local network

Newtech also involves traditional channels of interaction, in that Newtech funds post-graduate student bursaries and laboratory equipment for specific projects and hence, it is an important source

of financial support for the university research group. Likewise, there are service channels of interaction, but these involve direct and formal knowledge exchange. The universities consider their involvement with the firm as primarily a research partnership, on a consultancy or contract basis. One professor, for example, explained that he is on a retainer as a consultant, motivated to supplement his university salary but also to do applied research to the benefit of the university and industry.

Most significant is that the university is involved in bidirectional channels of interaction, in which knowledge exchange is intensive, bi-directional and mutually beneficial. This occurs at the local level, between the partners in the network. Research directions are identified that attempt to balance the academic interests of the scientific community (to yield academic publications and post-graduate theses) and the needs of the firm. This has resulted in joint publications for example. It also occurs at the global level of the network. The university professors, the private research company and the Newtech technical team form a research committee that drives and manages the R&D outsourced to foreign universities and research institutes. Depending on availability and the type of involvement required, the research committee selects the best partner to work on a specific contract. Researcher exchange is another important bidirectional channel of interaction. Members of the research committee have spent time at the US universities to train the researchers and teach them how to use the UV technology equipment. Privateresco technologists are available as a resource for the trials, and may assist in making up samples. Reciprocal university exchange visits with guest lectures, technology transfer and new research ideas generated are common. Another bidirectional channel is access to cutting edge high technology research facilities and infrastructure that are not available in South Africa.

Finally, there is a degree of direct research collaboration. There is a sense on the part of the local academics that the foreign partners will be conducting replication research, motivated by a lack of trust by regulatory authorities in the veracity of South African research, and that hence, the research conducted by foreign university partners will be overseen closely to ensure that experimental setup and protocols are followed strictly. Reporting and queries from the foreign research partners are referred to the research committee and they liaise with the foreign universities, directly or via Newtech. For instance, members of the research committee meet weekly and monthly with the US-based university research teams to go through the research protocols, and the American researchers send raw results for independent interpretation and discussion. There is thus a high degree of mutually beneficial knowledge transfer between the local and foreign universities. The possibility of future research collaborations arising from the network is an important knowledge benefit. As an emerging country firm pursuing its own network, the opportunities for interactive learning and knowledge transfer are high.

6.3 BRAZIL: TRANSNATIONAL IN THE AUTO INDUSTRY

Amongst the automotive companies established in Brazil, Fiat, Volkswagen and GM have adopted a strategy with greater decentralization of product development activities. On the other hand, Ford has adopted a strategy of greater centralization of its research and development activities, notwithstanding some recent evidence of changes in the company's strategy.

Fiat has followed a decentralization trajectory oriented by a competitive strategy attributing greater importance for volume and diversity, in addition to greater attention to the segment of small economy cars – which is also considered an entrance segment. The experience and accumulation of capacities, initially with the participation in the development of the Uno and then of the Uno Mille, contributed to the development of the Palio project. This was an initiative of the headquarters,

aimed at creating a vehicle for the developing country market. The Palio platform, originally created in Italy, was then transferred to Brazil, where it was later re-styled and had its derivatives developed. The technological capacities grew with the accumulation of knowledge related to the development of this kind of product (Dias, 2003; Consoni and Quadros, 2003).

The greatest evidence of an increase in the R&D activities of the manufacturer's subsidiary is the construction of the Giovanni Agnelli Development Pole inside its plant. The Pole, inaugurated in 2003, has got the conditions and capacities to develop the design of a new vehicle, build prototypes and conduct tests for validating technical solutions. The Style Centre, a part of the Development Pole, is Fiat's only design conception area outside Europe. Moreover, the Pole has got a Project Engineering area comprising Chassis, Electrical and Electronic and Coachwork Engineering, as well as an Experimental Engineering area comprising, amongst others, an Electromagnetic Compatibility Laboratory, an Electroacoustic Laboratory, Photometry, a CAN Network (onboard electronics) and Road Simulators.[36]

Although these activities demonstrate an expansion of R&D activities in the firm's subsidiary, research activities remain concentrated in Italy's Development Centre (CRF) and its interactions with other manufacturers, with headquarters of large suppliers, and with universities and research centers located in Italy and in other European countries.

6.3.1 Centro Ricerche FIAT (CRF)

The CRF was created in 1976 as a concrete action of this effort focused on R&D and on the innovation within the Fiat Group. Located in Orbanasso, around Turin and near the Mirafiori industry (the group's main automobile production unit in the country), this centre, in its structure, comprises research and development for numerous factories within the group, such as Fiat Automobiles itself and the factories of Lancia, Comau, Magneti Marelli, Iveco, Teksid, amongst others. The majority of those companies keep research centres within their own structures to develop and enhance its specific products. What makes the CRF different from those structures is its focus on basic research and on the partnership with universities. The academic competences of the latter contribute to greater innovations in the projects and solutions for the group as a whole. The Centre is described by Fiat itself as being the group's hub of excellency, whose mission is to boost innovation as a strategic factor in the company businesses.

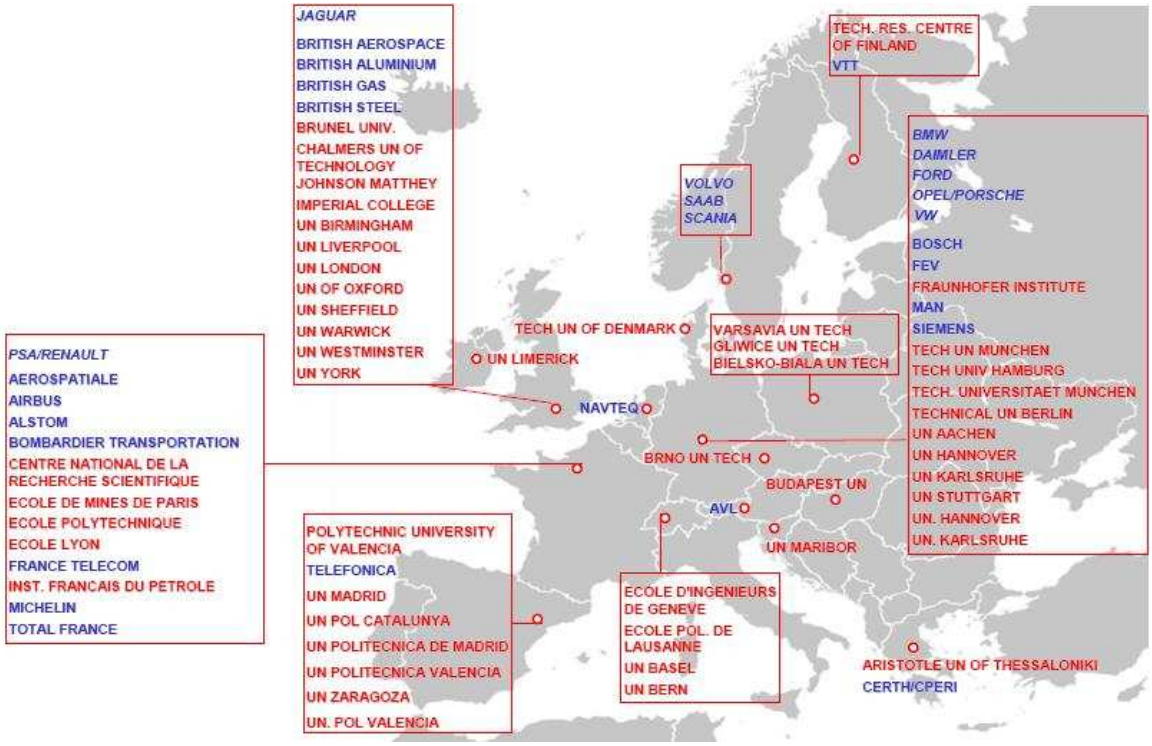
The CRF counts up 850 employees majored in numerous courses (mostly engineers and physicists) and has subsidiaries located in four other regions in Italy: Bari, Udine, Foggia and Trento. The

[36] There is history of centralization-decentralization of R&D of FIAT. Lemos et al (2000) work on the production system of Fiat's supplier network showed that during the 1990s, with the trade opening and the increase of foreign companies in the country's market, the R&D activities in the region were reduced. They were transferred to other countries and centralized at the headquarters' departments, so as to avoid the duplication of efforts and costs. Moreover, Fiat's engineering department, which employed 400 persons before the economic opening and the appearance of the "global car", was reduced to less than 100 employees. The centralization of these activities at the headquarters was a decisive element in explaining the low integration between the manufacturer and the auto parts companies, as well as between the companies and universities or public research facilities. However, more recent studies (Dias, 2003; Dias; Salerno, 2003; Consoni; Quadros, 2003) indicate a reversal of the situation. During the current decade there is occurring a process of decentralization, and technological innovation activities in the branches of Fiat and of other manufacturers have been increasing. Nevertheless, these studies indicate that, although with differences between them, the growth of R&D activities is related mainly to product development, with little or no efforts directed to research. The latter remains concentrated at the headquarters.

Trento unit exists since 2001 and has been created to generate solutions to the Fiat Group's problems and this cooperates with the main stakeholders in the area. The centre had been set in Trento to take advantage of the local market spill-overs and due to the Trento University's renowned competence in areas of interest for the CRF. Take for instance areas such as logistic and urban mobility and compact vehicles. Gianni Morra, Fiat's quality director, stated that the subsidiary has been set in this specific region due to the quality and excellency of the university.

Fiat's Research Centre holds a global network with more than 150 universities and research institutes, in addition to thousands of industrial partners, which reinforce the entire group's innovation strategies.37 The group interacts actively with universities in the Americas and Asia, and these are its main partners in Europe:

FIGURE 6.4 CRF European partners



Source: CRF

The CRF is Italy's biggest private research Institute and promotes initiatives that stimulate technologic and industrial development all over Europe. Amongst the European Union programmes for the research, there have been more than 500 funded projects, all of which paired with universities in the continent or with other companies, whether from the automotive sector or others.

[37] Data provided in an interview given by the Director of Relations and Qualities of the CRF, Mr. Gianni Morra.

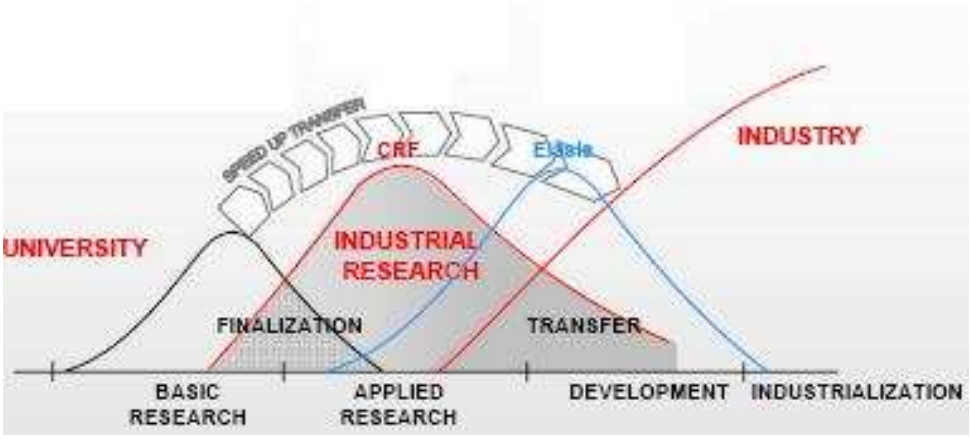
These projects are developed with Universities because they are greatly supported by the government, as to research. Many times, in order for a project to be funded there must be some type of cooperation between the universities' research and some companies' industrial research. Besides the obligation imposed by the fomenting agencies, companies such as the CRF choose to work with universities and public research centres due to their different competences in certain areas, thus contributing advantageously to all partners.
The main reasons for the interaction with companies belonging to other industrial sectors relate to the complex network of systems, subsystems and components suppliers that constitute the automotive sector and its technologic traffic. Much of the technology used in automobiles is generated in high cost and low production industries, such as aerospace, military and aeronautic sectors.

In 1988 the Fiat Group implemented another initiative called ELASIS. It is about a private research agency whose structure involves the complete industrial innovation cycle, starting with the industrial research, product development and engineering processes, such as studies regarding technical and economical viability and design, amongst others. The difference presented by the ELASIS is the ability to operate the research and production competences in an integrated fashion, always contemplating the final product to be used by the companies.

The research agency developed strong relations with the academic world, bonding with universities and Research Institutes to improve its design and development activities and the tests for new vehicles.

In 2006 and 2007 the ELASIS and CRF activities were integrated to create an innovation pole within the group. Specific areas of excellence have been shared, improving the centres individually and strengthening the ensemble. According to Fiat itself, the university develops the basic research, the CRF deals with the beginning of its applications, accelerating the knowledge transfer into the company and, and paired with ELASIS, which focuses on matters from the research applications to the development of the product to be industrialized, manages to connect the associated universities to the industry.

FIGURE 6.5 – CRF Innovation Model



Source: CRF

6.3.2 The Innovation Within the Brazilian Fiat

"The automotive industry settlement in the state of Minas Gerais has started with the growth of a big factory of international production: Fiat."(GARCEZ,2001).

Most suppliers was located in Sao Paulo as there was not a previous auto industry tradition in the region, which was justified by the production in reduced scale. The production increase led to the rapid growth of the internal market and by adopting a just-in-time production model, the minerizacao was promoted, thus attracting suppliers to sites closer to their consumers, such as the Fiat group own companies. This process narrowed the non-essential activities to the manufacturer, which broadened the production unit, establishing a new relationship between the company and its suppliers. (LEMOS; DINIZ, 1999).

Guided by the demands of the automotive industry, the national suppliers initiated joint-ventures with foreign companies in order to gain technological knowledge regarding vehicles produced in Europe. Until 1997, only one of the thirteen FIAT suppliers was funded only by national capital. Many of these companies, whose capital was at least partially foreign and that were established in Brazil, operate paired with FIAT headquarters in Italy, supplying a line of products developed in joint projects of research and development. (CAMARGO,1996).

The technologic and innovative activities are strongly connected to the National Innovation System and consequently with the local system. The state of Minas Gerais has made efforts since the 1970's in order to promote a 'significant structural and industrial change state wide, toward a greater production diversity, that (...) led to a horizontal diversification for the automobile, mechanical, electro electronic and telecommunication industries." (LEMOS; DINIZ, 1999). The industrial cluster of the greatest importance in the state is undoubtedly the "mineral metallurgical complex", which comprises base industries.

By seeking a diversification of the industry in the state, its strategic location and public agendas, intensively executed by the government, to foment new companies have been explored. This effort enabled a better link between the state production and the industrial pole in the state of Sao Paulo.

The automobile cluster in Minas Gerais is relatively recent, as it has been set in Betim since Fiat's creation in 1976, but it has great importance and influence in the Metropolitan Area of Belo Horizonte. Fiat as well as its supplying companies, which have been established in the region after the "mineirizacao", have had a "key role in the industrial development of the state, gathering not only knowledge regarding technologic capacitation, but also induction to their suppliers capacitation" (LEMOS; DINIZ, 1999).

The Minas Gerais Local Innovation System follows the national pattern and comprises R&D institutes, whether public or non private, as it happens in Italy with Fiat's headquarters. It can be noticed that the predominance of public institutions also generates a predominance of basic research over its applications. The state hosts six Federal Public Universities and a big private Catholic University. All of them offer employees who are not only capacitated but also skilled for having taken part in the research developed in these institutions. Notwithstanding, Fiat maintains formal interactions with one of the Federal Universities (UFU) and the Catholic University (PUC-MG).

The institutional system of the state's public research counts on seven great research centres, most of which belong to the government and have grown and received governmental support under the same 1970's policy, which aimed at the betterment of the state's industrial structure. Fiat has a strong connection with the CETEC - Technological Centre of Minas Gerais - one that has been established since the construction of the plant in Betim. Another means for the state to positively influence the technological development in the region and enable interactions with Fiat is through fomenting agencies, ones that fund researches and projects undertaken in partnership with universities, research centres and companies. Fiat is the company with the highest allocated values for R&D projects funded by the government in Minas Gerais.[38]

6.3.3 The International Networks of Fiat

In order to better investigate and understand the concepts and hypothesis of this paper, a case study was made because, as this is a recent matter, which builds up a context that is not unattached to the study object, it has to be analyzed in a dynamic manner and better explored through a qualitative research method. (YIN, 1994; BRYMAN, 1989)

6.3.3.1 The Italian Fiat case

Fiat S.p.A is known for being a company that invests greatly in innovation, an aspect which is valued in all the group's companies. The creation of the CRF and of the ELASIS is a proof of this. Fiat set these companies within the group aiming at profitable results and counting on the share participation of all the companies that belong to it, such as Ferrari, Magneti Marelli, Fiat automobile and Comau, amongst others, to manage the interests in innovation and research in its different sectors of production and actuation.

[38] According to BDMG's data, 1996.

The CRF and the ELASIS, both have dealt with over 2 billion euros in researches for the Fiat group, for partner companies and for the European Union, which is responsible for the biggest part of the public finance used. The whole of the Fiat group employs about 14.500 employees in 118 research and development centres, scattered in the company's units all over the world. The CRF employs about 800 researchers, amongst engineers, physics, economists, etc., whereas ELASIS has 1200 employees dedicated to researches on Fiat products.

Those two units of research have reaffirmed the company's tradition of cooperation with universities and research centres since it was first established.

The interaction with these partners has evolved throughout the company's existence, which led to informality and nowadays upon a simple cooperation the contracts are oriented thusly:

- Problem-solving Orientation: Related to processing problems within the companies, which normally involve some kind of routine. The University or research centre acts as a consultant regarding its competences.

- Orientation through research: A broader contract is created in order to enable the funding of researches within the University. The contract is based on strong bonds and interactions between both parts and has a formal and clear goal, which is established from the beginning.

- Sponsorship: This sponsoring created by the company establishes a less strict relationship between the parts. The resource is given to the University in order to help and stimulate certain types of research, with a bigger scope and less controlled. Most of the time, the research has no pre-defined formal goal.39

The informal relationship between the CRF, the companies and the Universities is still seen as being quite strong and of great influence for many projects. The interviewees pointed out the connection that the company's employees keep with the Universities where they have graduated and their closeness to teachers, researchers and research groups and that certainly influences some projects developed within the company and facilitates the rising of less bureaucratic solutions. This practice is widely encouraged by the CRF that offers support and tries to strengthen this type of bond and communication.

The Fiat group states interacting with over 150 universities and research centres all over the world. Lately, all these interactions and cooperations are formalized and made possible through freework agreements by the CRF and ELASIS, which are responsible for intermediating projects between the universities and the demands made by sectors of the Fiat group. In most of the cases, these projects are developed in the research centre where everyone is involved.

As a means to identify these Universities and Research Centres expertise, for future cooperations, the CRF is developing a database to monitor competences and abilities of possible partners with whom it has already worked with or that have a good reputation in the company's areas of interest. This database is built upon an evaluation of results provided by these institutions though publications, funded research projects, internships, thesis, bibliographical references, patents, contracts, cooperations, etc.

Amongst the over a hundred universities which are partners of the Fiat group companies and the CRF and ELASIS, it is important to highlight the Turin Polytechnic. Due to the proximity of the

[39] Information provided in an interview with the Centro Ricerche Fiat (CRF) Law Department representative in Orbassano, Italy

institute, it was the unit where most of the Fiat group's employees have been trained. It has also been greatly influenced by the presence of the Turin automotive pole, thus becoming a determining agent in the company's history.

6.3.3.1.2 The Turin Polytechnic and the Automotive Engineering course

The relationship between the Turin Polytechnic (PoliTo) and Fiat S.p.A. has rapidly surpassed the activity of simply providing qualified personnel. From the beginning of its activities, Fiat has developed project paired with the institution. These projects are a world wide reference in engineering. According to the CRF representative, Mr. Gianni Morra: "Being connected to PoliTo is a strategy."

Those interviewed at PoliTo have identified the physical and social presence of Fiat in the city and in the entire Piemonte region as being one of great influence to the learning process and to the research in the institution. This influence allowed it to be recognised in engineering areas such as mechanic, automaton, physic, amongst others. The have also recognised the important role that the polytechnic has in the company's successful history, not only for providing qualified personnel but also for all the competences spill-over they generate, due to the proximity with the factories, headquarter and research centre.[40]

The cooperation between the Turin Polytechnic and the Fiat group has been formalized along with the supporting innovation policy, which led to setting up the CRF in the company. Nowadays, the PoliTo is the biggest Fiat's partner in the education sector. The partnership has evolved in such a way that the Automotive Engineering course (*Ingegneria Dell'autoveicolo)* was created in 1999 to see to Fiat's internal demand for professionals whose area of expertise is entirely focused on its production process. The intention of capacitating the employees better has evolved to the improving of the group research projects, leading to a betterment of the competences for the institution and for Fiat itself.

According to the Automotive Engineering course coordinator, the course only exists due to Fiat's demand. The Automotive Engineering Faculty set in Lingotto is the only one in Europe to provide graduation and master courses focused on automotive vehicles and is also the first to do so internationally, since one can take the entire course in English. Nowadays, there are 60% of Italian students in the course, and the rest are mostly from China, Korea, India and Brazil, Fiat's host countries.

The Turin Polytechnic, at the time, already had a recognised course of Mechanic Engineering focused on automotive engineering that has been kept by that institution. However, structuring the new course respected the patterns set exclusively by Fiat. The company was responsible for developing the syllabus along with the PoliTo course professors, it funded the project, donated the faculty's installations, provided material for the classes and its employees represented 70% of the body of professors, which nowadays was reduced to 30%. Presently, there is a big complex that includes the faculty, a public shopping centre and the Fiat's administrative headquarter in that region.

[40] Interview given by the Coordinator of the PoliTo Automotive Engineering course, professor Giancarlo Genta; by the PoliTo International Relations Director, Mrs. Elisa Armando (on 16/11/2009) and by the responsible for the university-industry project from the *Associazone Tecnica Dell'automobile* (ATA), Mrs. Roberta Reggiani (on 17/11/2009).

In 1999, the year the course was created, Fiat's 100th anniversary was celebrated and, after 10 years of its existence , in 2009 revisions were made in the contract firmed between PoliTo and Fiat and it was coordinated by a comity comprised of their entities members. The new contract has kept the structures that proved to be successful throughout these years and brought as a new topic the creation of a research centre in the faculty et in Ligotto, thus emphasizing the integrated research between both institutions.

The relationship between the academic institution and Fiat is made by the CRF. The research centre passes the resources onto the faculty and structures the contracts of consultancy and rendering of services. These contracts will then be formalized for the development of the activities, in which case both parts are interacted. The course's mandatory internship is done by 90% of the students in any of the Fiat group's companies, the 10% left work in the faculty doing some project or research.

The Lingotto Faculty develops projects and collaborates with other companies in the automotive sector. A big project is being developed with GM PowerTrain. These partnerships allow the exploration of new competences in the automotive sector, improving the quality of the course and bringing greater recognition and quality to the institution.

For being Fiat's biggest partner in the academic area, PoliTo has already been contacted by the company to consult it in the creation of automotive engineering courses in other regions where the Fiat group acts, such as Turkey, Poland and China, as a means of reproducing the successful Italian experience in which the University acquires competence and know-how, when it comes to education focused on qualification for any given industry. IVECO, one of the Fiat group's companies, has created an internship to capacitate its new employees in China which has included graduation studies, provided by the PoliTo and formatted as an MBA in vehicle production to be directly applied in the Italian factory. This initiative aims at transmitting the culture and the productive structure of the company for the new chinese subsidiary.

6.3.3.1.3 The *Phylla* case

A very interesting project that shows the cooperation and the interaction in the Italian headquarter with its regional partners is one of an experimental urban vehicle moved by solar energy. It presents some sustainable technologies such as electric propulsion and PV panels.

Seeking for alternatives to improve the mobility, the Piemonte Government proposed and funded a project to develop an automobile that took into account financial and environmental issues. The project is coordinated by the Turin Polytechnic paired with the Ricerche Fiat Centre and counted on the participation of other agents of the region's automotive sector, two other universities: The European Design Institute - IED and the Applied Arts and Design Institute - IAAD and regional companies such as the Camera di commercio di Torino, Hysylab - environment park, Novamont, Proplast, SAGAT, SYDERA and Pirelli, amongst others.

Phylla, which means leaf in ancient Greek, has got the ability of transforming solar energy into propulsion for the vehicle. The project meets the requirements of being electric and sustainable, ecologic and completely recyclable, economic, multi-functional and connected. The vehicle created

as a Fiat's prototype is used as an experiment of innovation. The CRF uses Fiat to test its new technologies focused on more sustainable solutions to be applied in its commercialized products.[41]

This project was able to connect different partners, amongst which the universities, the government, Fiat and other big companies, in addition to small regional companies that could develop a big project in the automotive sector.

6.3.3.2 The Brazilian Fiat case

The Brazilian Fiat differs from the headquarter for not having the same history as a company. Whereas the Italian headquarter has been through the same innovation stages in production, learning and development during its 110 years, the Brazilian subsidiary has been created with competences, structures and production culture inherited from the headquarter. A company need innovation to exist and be successful, whereas the subsidiary reproduces the successful experiences of the headquarter.

FIASA, Fiat's Brazilian subsidiary, has been created with a strong policy of research and development of technology, originated in Italy. The company was established with the vocation to invest in partnerships with universities, research institutes and other institutes. However, the peculiarities of the new place have arisen different perspectives for the development of products.

According to the FIASA interviewees, Fiat in Brazil initially had to follow innovation plans and models created in Italy and focused on the Italian industry reality. The new subsidiary has taken a long time to develop its own innovation culture to adapt the Italian directories to the Brazilian reality and to obtain the required independence that would allow the investment in innovations regarding the national market and possibly the global market.

After 33 years of existence, FIASA stands today as Fiat's south american pole, responsible for coordinating and centralizing competences for industries set in Argentina, Chile, Venezuela and Mexico. The Brazilian Fiat employs about 3.000 engineers in 8 R&D centres set in the different companies of the group. Fiat automobiles alone employs 800 of the personnel dedicated to innovation activities.

FIASA has acquired competences and its own capacities paired with over 40 Brazilian universities and uses this interaction between universities and companies in its favour. Creating corporative universities or internalizing all the research and development, taking maximum advantage of the academia and the specificities provided by these institutions, are not the company's policy. [42]

FIASA representatives affirm that currently there no longer is a technologic discrepancy between the Italian factory and the Brazilian one, but local markets specificities. One of the examples given was the Automotive Suspension Centre of the Brazilian company, which has become a reference to the world in its area of expertise. This expertise and leadership has only been achieved due to the need risen by the bad condition of Brazilian roads, that demand very advanced suspension technologies. The CRF recognizes, for example, that the research and development in the biofuel field must be centralized in the Brazilian subsidiary. The Betim factory has competences and local

[41] Project presented during interview on 17/11/2009 at the Centro Ricerche Fiat, in Orbassano, Italy.
[42] Information obtained in interview on 03/11/2009 given by Mrs. Silvana Rizzioli, from the Fiat's Competence Centre and by Mr. Raoni Bagno, from the Fiat Powertrain Innovative Committee (FPT)

advantages, which derive from the experience in producing cars of the type Flex. This justifies the centralization of the studies and development of tests and products, avoiding doubling the costs for the group.

6.3.3.2.1 The Fiat PowerTrain (FPT) innovation Master-plan

Fiat Powertrain was established in 2005 and gathers all the Fiat Group's innovation and expertise in development, production and motor and transmission sales for the most diverse usages. This is a different situation as it segregates in one single unit the production of motors and transmissions, gathering know-how and competences of different companies in the group (Fiat Automobiles, IVECO, Lancia, etc) that had already produced motors and transmissions previously, making it possible to mend all the experience and excellency acquired by different companies within the unit.

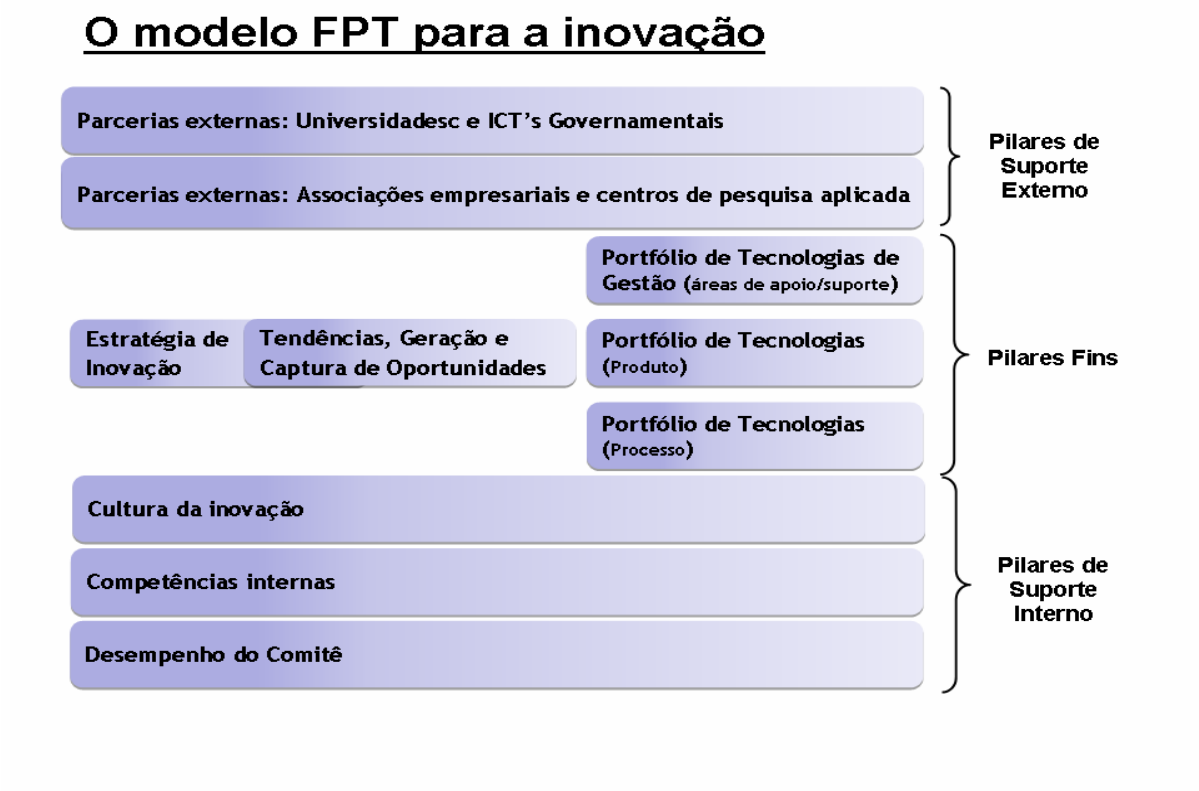
Fiat Powertrain (FPT) holds the master-project of innovation for the entire company in Brazil. The model has been developed and applied in this unit, in ordered no to be pursued by the others.

This project includes a mapping of universities likely to become company partners, as the group aims at developing a partnership and cooperation in joint projects with educational institutions. Numerous technical visits to universities have been made, including interviews with those responsible for areas in which FPT is interested and visits to laboratories intending to identify common goals. In addition to universities that are already partners of the company, such as UFMG, UCS, USP, UFSC, PUC-MG and DFC, other institutions, potential partners in the future, have also been monitored.

FPT invests greatly in research and development and for being an independent company with its own profit goals also works with companies outside of the Fiat group, including the competition.

The Fiat PowerTrain plan used by other units follows the concepts below:

Figure 6.6 -Fiat PowerTrain Innovation Master Plan



SOURCE: Fiat PowerTrain

6.3.3.2.2 Interaction with the Universities

The long partnership between universities and public research centres is considered one of the pillars of external support for innovation in the whole of the Fiat group. Research groups that maintain cooperative projects with Fiat have been identified through information from the National Council of Scientific Development, they are PUC-MG, CETEC and UFSC.

The Federal University of Santa Catarina (UFSC) interacts vastly with Fiat and does so through virtual means of communication, due to the distance matters. The physical distance is seen by Fiat as a difficulty for deeper partnerships and for the recognition of the partners' competences. UFSC is a university that has been created as a response to the need for industrial development in the region and that is why it has a focus and a history that differ from other institutions and a greater call for partnerships with production units.43

CETEC - Minas Gerais Technologic Centre Foundation, has been Fiat's partner since the factory's installation in Betim. CETEC has been nominated by the state's government as the responsible for aiding Fiat in the factories constructions and since its inauguration it has kept an annual contract of cooperation and service rending with the Fiat Group.44

[43] Information provided by Mr. Raoni Bagno, from the Fiat Powertrain Innovation Committee (FPT) in an interview on 3/11/2009.
[44] Information provided in an interview by the coordinator of the CETEC electro mechanic sector, Mr. Jose Eustáquio da Silva, on 29/10/2009.

Fiat keeps at least one employee working full time in the CETEC laboratories who focus on the development of problem solving activities for the company.

Fiat has made several investments in the CETEC technological structure summing to 8 million reais, which enabled the building of a new laboratory to test the performance and the components of motors, amongst other activities. Fiat has also intermediated the contact between CETEC and CRF in Italy, so that some projects received technical resources from the research centre, which is a world reference in the automobile sector.

Minas Gerais Catholic University (PUC-MG) initiated its relationship with Fiat in 1991. An encouragement to establish relations similar to those between Fiat and the Turin Polytechnic in Italy was given by professor Djalma Francisco Carvalho after contacting the company. A capacity for quick responses to the company's demands is recognised in PUC by Fiat, which facilitates and stimulates the interactions between them.[45]

At the same time the partnership was firmed, PUC initiated the Mechatronic Engineering course, one that would respond to some demands from Fiat's personnel. Before that, the company would send employees to Italy for them to get proper training. In 1995, the University along with the company created the Master Fiat, the Fiat/PUCMinas MBA. As part of the partnership established, whose main target was Fiat employees that would develop academic projects and keep their graduation within the institution, nine professors of PUC-MG Mechanical Engineering course were sent to train the staff at the Fiat Ricerche Centre where they could work, develop projects and create what the company called: automotive Culture in the University.

From this exchange, the relationship was set between PUC-MG and Turin Polytechnic, situated in the same region as CRF and one of its main partners.

Currently, the post graduation course was no longer called Master Fiat and became a masters stricto-sensu in Mechanical Engineering, regardless of the company. However, a big part of its target public comprises employees from the group's factories. Both partners managed to reach a deal for the classes to be given on the days the students did not have to work in order to study.

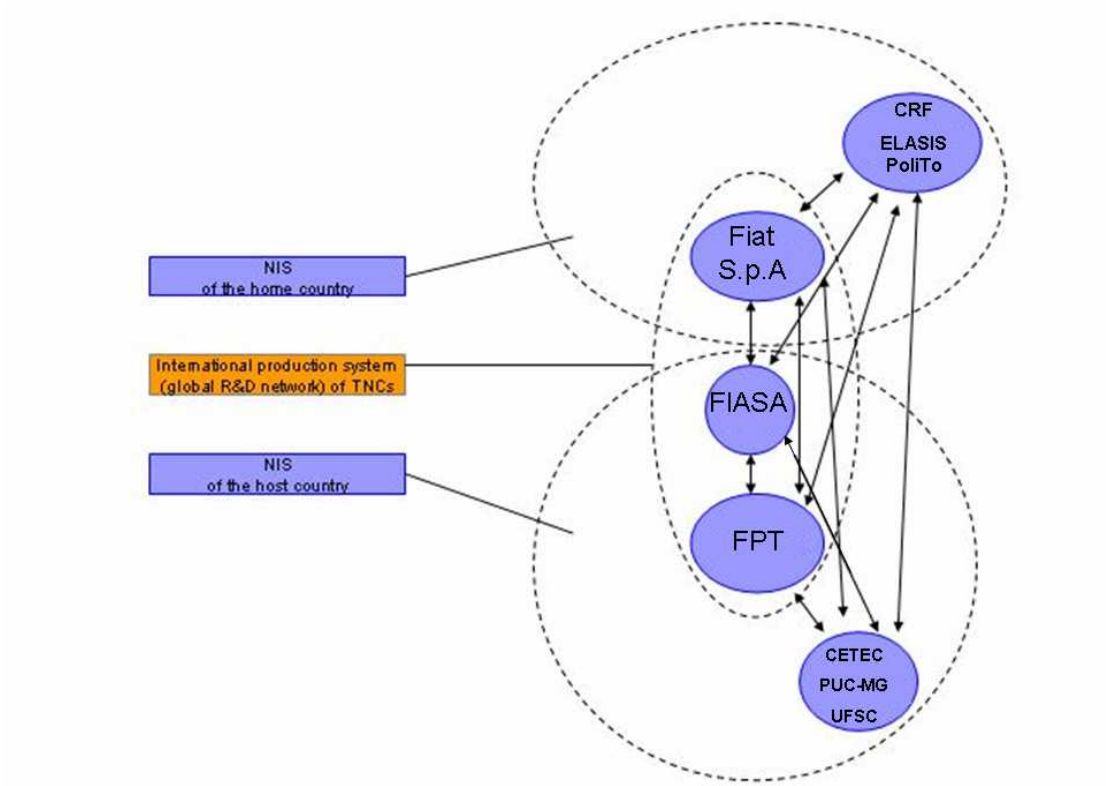
Fiat also has numerous projects developed with the research groups and professors of the University in the form of consultancy, partnership or service rending. In spite of the fact that most successful partnerships are seen as originated from the work done by the company's employees who are also students at the University, the rest of the joint work have generated several investments in the university's structure, such as laboratories and educational materials.[46] In a specific study made by professor Sergio Hanriot in direct partnership with the Turin Polytechnic, it has been created due to the research done in a new testing laboratory in the Mechanical Engineering building at PUC-MG.

[45] Information provided in interview given by professor James Landres, director of IPUC on 07/10/2009.
[46] Interviews given by professor Sergio Hanriot and professor Eliene Lucas from the PUC-Minas Mechanic Engineering department.

6.3.3.3 The Innovation Network between the two Spheres

In order to grasp a better understanding of the Global Innovation Network within the Fiat Group, in other words between the Italian headquarter and its Brazilian subsidiary, it is advisable to return to the point made in the first chapter's scheme and identify key elements and flows in the network.

FIGURE 6.7 - Fiat's Global Innovation Network



Source: Author's elaboration

The Figure displays some of the agents involved in the GIN identified within the Multinational Fiat Group. These agents are certainly the most important of the entire configuration as well as those with whom we have been in touch, to obtain data and evidences.

The arrows that represent the flow also have different intensity and importance levels and, although it is not represented in the Figure, it can be noticed that the existent flows in the international production system involving Fiat S.p.A., FIASA and the Brazilian FPT. Those are more intense and natural flows. These connections are configured inside the multinational and, for having commercial and lucrative goals, are easier and more important to the agents.

As it has been observed, the Italian Fiat and its Brazilian subsidiary recently have displayed a work flow that works as "a two way street in the product development".[47] Just as the Headquarter is

[47] Mr. Raoni Bagno's statement in interview.

responsible for most decisions, regarding innovation within the group, and also transfers most of the technology to its Brazilian subsidiary, in time FIASA has made its way in the group and nowadays stands as a reference in some of the company's sectors, gathering responsibilities and great investments when it comes to the inner research and development.

The arrows that have the peripheral flows, connecting the agents that stand outside of the international production system, has a great facilitator that has not been mentioned yet, and that is the Minas Gerais Government. The government has, within the State Secretary of Science, Technology and Superior Education, an area dedicated to the Assembling of Resources and International Partnerships and maintains an intense relationship with the Brazilian Fiat's competence centre. In the past years, a bond between the Italian Fiat and its partners in the Piemonte region and the Minas Gerais government has been created.

The agreement was signed by the Governments of Minas Gerais and of the Piemonte region in November, 2008, in Turin, Italy. The agreement aims at a greater cooperation between both regions and, through Fiat, focuses on some questions related to energy and infomobility. On the same day the agreement was signed in the Piemonte region, other secondary agreements were made between other agents from Fiat's Global Innovation Network.

Sergio Marchione, Fiat S.p.A. president signed on the same day an protocol of intentions with the Brazilian Fiat representatives, CRF and PoliTo, for the cration of a Ricerche Fiat Centre in Brazil, the CRFbr. The intention protocol has not been turned into a formal deal yet, but the interviews given both in Brazil and in Italy indicated that the project is being developed and intends to foment even more the innovation activities in Brazil, raising the importance of the Brazilian factory in the multinational context.

Another deal, also as an intention protocol, signed during the event, involving PUC-MG and the Turin Polytechnic to create a two way major for Mechatronic students, a course given both in Brazil and in Italy. Such an agreement would possibly include Fiat as a partner in order to provide internships in the group's factories of both regions.

This effort is the result of a policy initiated by Silvana Rizzioli, responsible for the Fiat's competence centre, in order to develop the education and the study of the automotive area in Brazil. This effort aims at reproducing in some aspects a successful practice adopted in Italy and for that it counts on the Turin Polytechnic as its main partner, given its tradition of improving the quality of the education.

Ever since the protocol was signed in 2008, there has been a student exchange that involved a group of 15 students from the Polytechnic brought to Brazil for a month to attend classes in Belo Horizonte both at PUC-MG and UFMG. They have made several technical visits to the factories in the region. This group study concentrated in biofuel, one of the themes to be focused on according to the Minas-Piemonte deal.

Another project presented by Fiat, during the interviews was the one that predicts the launching of a car that is 100% Brazilian. Fiat will launch in 2010 a car that will have been completely developed in Brazil, aiming at exporting it or reproducing it in other markets.

6.3.3.4 The Locker case

A project that represents the new reality of Brazilian subsidiaries as a source of innovation for the entire group is the one that has developed the Locker transmission system.

The markets in Italy and in Brazil have common demands for the off-road automobile market. Both needed enhancement in the performance of traction in vehicles for situations where there is low adherence to surface (In brazil soils with mud, rocks and sand, whereas in Italy snowy soils too). The headquarter could solve this problem for vehicles whose traction is not 4x4 by slightly altering the ABS breaking system, mandatory serial items for European cars, locking one of the wheels and overcoming the low adherence to surface problem.

For the Brazilian market this was not a solution, as ABS brakes are not mandatory serial items and represent a very high cost in the final value of the vehicle making it unappealing for consumers. Facing this scenario, Fiat Powertrain has used its expertise in the agriculture machinery market and proposed to install a locker mechanism in the vehicle's transmission. When powered by the driver the system allows the front wheels not to spin at the same speed as the rear ones, thus compensating for the low adherence situation and avoiding squidding or losing control of the vehicle (BAGNO; MACHADO; FRATTA, 2008).

The solution found by the FPT costs approximately R$200 for the Brazilian factory, whereas the solution found in Europe would cost about R$2000. The project counted on the cooperation of other Fiat group units, as it asked for competences from a research that had been developed by the Headquarter for a new material to be used in the transmission. As this new material would be strategically produced in the polish factory and the electronic part would be better developed in the Korean unit, the project has also required the headquarter's knowledge on the logistic of chain production within the group. Parts of the transmission have been strategically produced in Poland, Mexico and South Korea, given the region's advantages, and have been assembled in the Betim factory, then exported to the rest of the world.

After the development of the project that proved to be successful and can use all of the Fiat Group's production network, the Italian headquarter chose to use the system that had a lower cost than the first solution that had been proposed.

6.4 CONCLUDING REMARKS

It is important to stress that although the relative share of foreign R&D in South African agro-processing (7.8%) and Brazilian automotive (89.7%) are vastly different, the case studies identify extremely similar dynamics around innovation, and that the nature of interaction with local universities is strongly alike. The difference in foreign R&D investment seems to have no influence on the nature of the local R&D and the local connections established by the local subsidiaries of TNCs. This may signal the role of the position of the host country nation in the network formed, and the influence of the country's NSI on the nature of the linkages established (as we have argued, both countries would be categorized as immature NSIs).

In both country cases, the location of subsidiary R&D is deeply hierarchical (as Ernst, 2009, highlights for Asian cases), and there is a clear division of labor between central and peripheral R&D departments.

This hierarchical relationship is not static, however: over time, at least in the case of Fiat, there have been improvements with the network between TNC headquarters and subsidiaries and their connection with universities. Once a team in charge of local R&D activities has been formed, a new process is created, with its own new dynamics. The local R&D team learns how to deal with the

company's headquarters and how to fight institutionally for more important roles within the company's innovative network. These dynamic effects are also present in the relationship with universities, since there may be R&D researchers and engineers with formal connections to local universities (as teachers, for instance), who naturally establish ties between local universities and local R&D department. There will be informal ties, also, since engineers and researchers from the local subsidiary may take graduate courses in local universities and very likely use problems of the R&D department as the subject of their dissertations and theses. These informal interactions may develop over time, and may even be stimulated by R&D management.

Table 6.3 Comparison of R&D, innovation and interaction in the two cases

	Dairyco South Africa	Carco Brazil
Innovation strategy	Competitive strategy to promote the nutritional and health benefits of its products, rooted in an environmentally friendy operation Develop products with nutritional quality adapted to the profile and taste preferences of local populations	Competitive strategy focused on volume and diversity, focus on small economy cars (entrance segment) Vehicle platforms restyled and adapted for developing country market
R&D departments	Basic scientific research, clinical research and new product development driven by research headquarters in Europe - two principal research centres Hierarchical global network of R&D centres in 15 countries, some integrated into main business divisions, some transversal conducting scientific research on health and nutrition aspects of products	R&D and basic research concentrated in central Development Centre in parent company in Europe, the largest private research institute in the home country Applications research centre in Europe, to integrate basic research and product development for complete industrial innovation cycle 118 R&D centres in the MNCs units worldwide Development centre in Brazilian subsidiary plant, with the MNC's only design conception capacity outside Europe
Division of labour: Central R&D	Innovate and develop complex products, patent and roll out globally Network organizational culture, connect to country units through structured communication network and collaboration between central and subsidiary teams	Conducts all basic research Develops new vehicle platforms
Division of labour: local R&D department	South African group as base for growing regional markets: research unit with capacity and mandate to conduct internal R&D and develop new products for local conditions that may attract new markets Research into flavours, nutrients, textures and recipes tailored for South African market Intellectual property generated becomes property of the group New product developed in SA rolled out by subsidiaries in other countries and circulate through group	Brazilian group as base for regional markets: coordinates and centralizes competences for 8 R&D centres in companies of the group in the region Restyling of vehicle platform to suit developing country market Develop design of new vehicle, build prototypes and conduct validation tests Global leaders for group in niche areas related to local conditions
Where decisions taken	Innovation and research expertise primarily concentrated in headquarters and other developed economies Annual meeting to identify innovations of interest for entire group Countries organized in zones that communicate internally so that potential new products developed in one country may be adopted in others Limited range of R&D activities offshored to SA subsidiary	Headquarters have strict oversight of all product development Decentralisation strategy and increased independence of subsidiary, shift from pure product adaptation mandate Innovation projects in subsidiary driven by entrepreneurial individual champions
Collaboration	Country units collaborate on R&D, share expertise and resources with European and developing country partners Group prioritises scientific collaboration with universities and specialized research institutes, primarily in Europe and USA SA subsidiary has limited relationships with local universities, outsourcing on a contract or consultancy basis to tap complementary expertise, such as new packaging or nutritional analysis of new target markets, but not product development	R&D and innovation centres collaborate with broad range of universities and research institutes in home country (particularly a close collaborative partnership with the polytechnic in the headquarter city that includes a custom tailored automotive engineering programme) and across Europe, attracting EU and government funding MNC centre: chain of basic research in Eurpoean university, accelerated knowledge transfer in R&D centre, and process to development of product in innovation centre Interaction in the form of consultancy, contract joint research and firm sponsorship of university research, as well as informal exchange Brazilian subsidiary has formal interaction with local universities and public research institutes, in the form of extensive government funded joint R&D projects and exchange of university personnel to the R&D centre in Europe
Project example	Development of a low-cost, vitamin enriched product that can be stored at room temperature for a period of time, for low income market segment in emerging economies, marketed through a novel micro-distribution system based in townships with unemployed women as sales agents through informal outlets and door to door sales	Advanced suspension technologies developed in response to Brazilian road conditions, when financial viability verified by headquarters, spun out to involve different parts of the MNC as well as outside partners to finalise project, involving movement of local engineers to European research centre Biofuels studies and tests and products centralized in Brazil to take advantage of local competences and avoid duplication of costs

The framework designed to deal with global interactions between firms and universities yields four main types of interaction, with variations depending on their location in the centre or the periphery. This section presents two case studies in order to illustrate the veracity of the framework, from a developing country perspective.

The case studies deliberately cover different sectors in the two countries, agro-food processing in South Africa and automotives in Brazil (Table 6.3). Both may be classified as Type 3a, a TNC from the North interacting with both its 'home' universities in Europe, and with 'host' universities in the South. Type 1 interactions, between local firms and local universities, have grown in both South Africa and Brazil, encouraged through policy support, government funding programmes and other incentivisation and support mechanisms such as technology platforms, incubators and science parks (Kruss 2005, 2006, Rapini et al 2009, Albuquerque et al 2010). A focus on Type 3a allows elaboration of the nature of university interaction in the global innovation networks that are a feature of this phase of the internationalization of science.

A common pattern is identified in the two cases – the host subsidiary and host universities in the South play a subordinate role in the R&D networks of the MNC, indicating the strongly hierarchical nature of the global innovation network. Carco is a large automotive TNC that focuses on the segment of small economy cars, and has a large operation in Brazil established more than 30 years ago, which served as its centre to access Latin American markets. Dairyco is a large agro-food processing TNC that focuses on nutritional and health benefits of its products. It entered the South African market more recently, in the mid 1990s and the subsidiary has expanded rapidly as a base to access Southern African markets.

The innovation strategy of both TNCs are similar in that they aim to be technological leaders in their niche globally, and the subsidiary is tasked with adaptation for the local market. The structure of the interaction is alike. The TNC interacts with home universities, with the subsidiary and host supplier firms, as well as host universities and public research institutes in a hierarchical network, but also, horizontal collaboration networks with high reputation universities, research institutes and suppliers in the North (Figure 1.2).

R&D and innovation in both cases is organized on a decentralized model, with basic research and new applications research controlled by the central unit, outsourcing complementary basic and strategic research to the home country Northern networks. Interaction also takes the form of TNC sponsorship of research facilities, programmes or scholarships.

Design and adaptation to local market tastes or conditions is offshored to the host country networks. A shift over time is that with growing technological capabilities, rather than simple adaptation of mature technologies to facilitate production, the host networks are engaging in more complex and novel adaptations of a technology platform, as in the examples cited in Table 6.3 . The results of such incremental innovation may be adopted within the group, to host countries with similar conditions or the subsidiary may even become the centre of expertise for the TNC in that niche area.

At the same time, despite the similar dynamics and nature of interaction, comparison of the two cases serves to emphasise that there are different ways to be inserted in a hierarchical global relationship. Dairyco subsidiary has drawn on complementary university expertise in relation to marketing or packaging, with only a few instances of formal interaction, taking limited forms of consultancy research or firm sponsorship of university activities. Carco in constrast, has a greater number of links with universities and public research institutes, and these interactions take more knowledge intensive forms. The Brazilian subsidiary has built ongoing relationships in the form of human resource exchange (even between home and host country and between universities in the

home and host networks), customized education and training programmes in the host universities, joint research and engineering contracts, alongside consultancies or sponsorships.

The difference between Carco and Dairyco relates to the uneven match between the industrial and science systems within the (immature) national system of innovation in each host country. In Brazil, automotive engineering expertise in the universities has coevolved with the automotive sector, as a matched area of strength. Government policy and funding, particularly at the regional state level, prioritised the automotive sector as core to regional systems of innovation, and actively promoted and incentivized interaction. The South African automotive sector similarly, has more knowledge intensive forms of interaction on a wider scale.

The opposite is the case for the agro-food processing sector in South Africa - a mismatch between industrial and scientific capabilities. Agro-processing capacity in public research institutes and universities has declined steadily over the past few years; government funding has focused on technology platforms to promote interaction between universities and SMMEs rather than TNCs; and the extensive national prioritization of funding for biotechnology has concentrated on downstream agricultural processes.

The similarities and differences between the cases thus illustrate the way in which the role of universities in global innovation networks is shaped by both the strategies of TNCs and the level of development of the national system of innovation.

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CONCLUSIONS

The combination of the literatures on GINs and on interactions between firms and universities defines a new taxonomy of different types of global interactions between firms and universities. This taxonomy helps to unveil the variegated flows that are running between diverse countries. This taxonomy, which has seven types, starts with the more basic exclusively local interactions between domestic firms and universities, goes through increasingly intricate international interactions, and ends with the sophisticated international consortia. However, it is important to stress that there is no guarantee that the networks will progress from one type to another. On the contrary, progress from one type to another, say a progress from type 1 to type 4, from a local firm to a home-based TNC with connections with institutions in diverse countries, is rather complex and difficult process.

The proposed taxonomy helps to emphasize the importance of two actors: NSIs and TNCs. A careful investigation of TNCs, of their origin (are they home-based in peripheral countries?), brings decisive information to understand the relationships established by GPNs and GINs. The size, diversity and stage of formation of NSIs are also key to understand how those global interactions are formed and in which direction they evolve. The nature of NSIs impacts both on the quality of the foreign-R&D that one country attracts and on the number and nature of home-based TNCs. In short, the characteristics of TNCs and NISs are inextricably intertwined in the formation of global networks of the various types described by the taxonomy.

The taxonomy is also useful to identify GINs as a specific channel of global interactions – there are channels beyond GINs – and it also instrumental to investigate the role of hierarchies in those global interactions. The literature on GINs, especially Ernst (2009) has recently highlighted how hierarchies are shaped and reshaped within GINs. Since Ernst (2009) deals with emerging Asia, the cases of South Africa and Brazil confirm the hierarchical division of labor, albeit in sectors other than those investigated by the author (ITC-related technologies).

Changes in the existing hierarchies are not easy to happen. Our investigation has led us to believe that the current phase of internationalization of R&D is indeed reshaping NSIs, but it is also dynamically preserving pre-existing hierarchies. This is clearly stated by Jefferson, suggesting that the movements related to GPNs and GINs only reshape the international division of labor while preserving the technological hierarchies. According to him, "[j]ust as the phenomenon of FDI and R&D offshoring leads to spillovers that induce Chinese firms to establish rudimentary operations, the same pattern of offshoring is also motivating the United States and other OECD MNEs to upgrade and diversify their R&D operations in order to maintain control over the development and deployment of critical technologies" (Jefferson, 2007, p. 213).

The review of the literature, our tentative taxonomy, and the field work of the Project INGINEUS have helped us to evaluate one central question: whether global innovation networks in emerging countries are a path for improvement within the international division of labor or a blocking factor for the development of national innovation systems globally integrated.

Our answer is in line with a recent evaluation from Ernst (2009, p. 6 and p. 38): GINs may be a "mixed blessing", even a "poisoned chalice". On the one hand, the preservation of hierarchies is a barrier to more advanced, technology-rich, international interactions. On the other hand, existing GINs may, under certain conditions, trigger processes that may lead to technological upgrade of peripheral countries. However, as Ernst (2009, p. 38-48) emphasizes, public policies matter for a more positive development of GINs. In our theoretical framework, this is one feature of the NSIs determining the nature of GINs.

The pattern of GINs that would really contribute to the evolution of peripheral countries NSIs would be home-based type 4 and type 5 interactions, together with types 6 and 7. The real challenge is to have a NSI which is conducive to the involvement of peripheral countries in those sophisticated types.

The development of global innovation networks, the present phase of internationalization of R&D, the processes of NSI formation and improvement may provide South Africa and Brazil with new avenues to escape subordinate roles in global innovation networks. South Africa and Brazil may use other types of insertion in global interactions between firms and universities, beyond type 4, discussed in this paper. Type 2 can be a starting point to the creation of TNCs, type 6 may be a wise way to take advantage of broadly built networks. And, type 7 is a rich way to take advantage of the relatively more developed scientific international role of countries like South Africa and Brazil (and this is a feature that they share with India, Mexico and other immature NSIs that are in the intermediate group of Ribeiro et al, 2006). Finally, the creation of interactions coined as type 6 ("non-hierarchical networks"), could be an experiment in the way to a formation of a truly global innovation system.