

Interaction between TNC subsidiaries and the Host Country Innovation System

The case of TNC subsidiaries located in Brazil

Dirk Michael Boehe *

Abstract

There is an increasing concern about the function of Transnational Companies' (TNC) subsidiaries in host country innovation systems, particularly so in countries which are highly dominated by foreign owned companies. Interactions or links between R&D units of TNC subsidiaries with host country partner organisations can influence innovation dynamics in the host country. Yet, previous academic research suggests that the subsidiary's R&D role is an important variable in this context. Specifically, global R&D roles have been repeatedly associated with strong local links. Following this notion, the purpose of the article is to explore to what extent subsidiaries with global R&D roles maintain different types of cooperative links with host country partner organisations. Based on a study of four R&D units with global roles located in Brazil, we identified several factors that have impeded R&D units with global responsibilities to link up with the Brazilian innovation system.

1 Introduction

Whether or not Transnational Companies (TNCs) contribute to the innovation systems of their subsidiaries' host countries, particularly developing countries, is the basic research question of this study. TNC subsidiaries may contribute to the innovation dynamics of their host country when they interact with local partner organisations, such as suppliers, customers, research institutes and universities, since interactions can promote learning and innovation (Lundvall, 1988). However, subsidiaries may play different strategic roles in a TNC's innovative activities and interaction or links with host country partners may vary according to the subsidiary role. Therefore, the purpose of this paper is to explore to what extent subsidiaries with a specific R&D role maintain different types of cooperative links with host country partner organisations.

I will focus on a specific R&D role, this is, R&D units which develop new products for global markets or participate in global R&D projects together with other TNC units. It can be assumed that the impact of these R&D units is considerable because of three reasons: first, R&D units with global roles tend to possess higher technological capabilities than units exclusively focused on adapting foreign products to the host country market. Hence, the potential of learning is probably higher for host country partner organisations when interacting with these units. Second, R&D units with higher internal R&D capabilities tend to have a higher absorptive capacity (Cohen and Levinthal, 1990) which enables them to interact with research institutes and universities. Third, R&D units with global roles tend to put forth higher demand pressure on their host country partners, since competing in a global arena requires high quality inputs. Consequently, these R&D units may spur their partners' technological upgrading processes.

This reasoning is in line with research on subsidiary roles. The latter stream of literature explains global roles, such as centres of excellence, by 'technological embeddedness' in the

* Working paper, first draft, May 2004. Universidade Federal do Rio Grande do Sul, School of Management, Porto Alegre, Brazil.

host country environment (Andersson and Forsgren, 2000) or by the existence of ‘links’ between TNC subsidiaries and ‘local sources of competence’ (Frost et al., 2002). While these and similar studies are situated in developed countries such as Canada, Denmark, Sweden and the UK, little attention has been paid to the particular characteristics of developing countries and to the question of whether R&D units with global responsibilities located in developing countries also possess strong links with ‘host country sources of competence’ or whether they rather form ‘islands of excellence’ detached from their host country’s innovation system.

This question will be explored on two levels: (1) macro level: aggregate data from a major innovation survey provide the context of the more detailed case studies, showing some general patterns of cooperative links between TNC subsidiaries located in Brazil and local clients, suppliers, universities and research institutes; (2) micro level: four case examples portrait different types of cooperative links between R&D units and host country partner organisations and also explain why some types of links predominate while others do not exist at all.

The case analysis suggests that subsidiaries with *global roles* in R&D do *not* necessarily possess cooperative links with host country technology partners and, consequently, their contribution to the innovation dynamics in their host country is probably limited. I will argue that the existence of these ‘islands of excellence’ is possible due to low cost advantages in R&D as well as accumulated technical knowledge within the subsidiary. However, these advantages may not be sustainable in the long run and linking up to the host country innovation system would be beneficial for both, the TNC subsidiary and the innovation dynamics in the host country.

The paper is structured as follows. After a brief literature review, I will spell out the conceptual framework on which this study is based. The framework will be applied both to the macro and the micro level of analysis. The final section points to a less recognised form of interaction and mentions some implications for Science and Technology policy.

2 Literature Review

This study is based on the combination of two different streams of literature, one of them analyses TNC subsidiaries from the perspective of innovation systems and the second is rooted in management studies and focuses strategic roles of subsidiaries.

2.1 TNC Subsidiaries and Innovation Systems

The relationship between TNC subsidiaries and host country innovation systems seems to remain a controversial issue. “Innovation systems” are often considered as basically “national”, being an outcome of path dependent evolutionary processes and marked by idiosyncratic historical, cultural and institutional characteristics of a particular country (Nelson, 1993). As a consequence of this, TNCs, being fundamentally rooted in the history, culture and institutions of their respective *home* countries (Doremus et al., 1998), would probably be strangers within the innovation systems of their *host* countries, which have been characterized by different path dependencies and institutions.

In fact, TNC activities in developing countries are sometimes seen as elements that tend to increase technological dependence (Unger, 1988) and decrease regional technological capabilities (Young, Hood and Peters, 1994, p. 660), rather than contributing to the host country’s indigenous economic and technological development. And mainstream management literature makes evident that the focus is on sourcing knowledge from (and not necessarily contributing to) host countries’ innovation systems (see Doz, Santos and Williamson, 2001 as an example).

Hence, in order to avoid ‘getting stuck’ within national boundaries, exploring our research question seems to require a different approach which has already been recognised by some scholars. For instance, Narula (2003, p. 18) points out that the ‘pervasive role of MNEs [Multi-National Enterprises] in a globalizing world – and their ability to utilize technological resources located elsewhere – makes the use of a purely national system of innovation rather limiting’. Alternative approaches which go beyond national boundaries are ‘sectoral innovation systems’ (Breschi and Malerba, 1997) or ‘Technological Systems’. Both of them differ from ‘national systems of innovation’ in that they are dynamic approaches; yet, while sectoral systems focus on the dynamics of competitive selection, technological systems focus on ‘how well the system can identify, absorb and exploit global technological opportunities’ (Carlsson et al., 2002, p. 237) and on ‘networks of agents interacting in a specific technology under a particular institutional infrastructure and involved in the generation, diffusion and utilization of technology’ (Carlsson and Stankiewicz, 1995, p. 49). Here, we opted for the latter approach.

According to the concept of Technological Systems innovation occurs in networks of buyers, suppliers and research institutes that may transcend the borders of individual countries (Carlsson, 1997). Technological Systems are based on ‘competence’ or ‘problem solving’ or even ‘informal networks’. Thus, particularly in economies highly dominated by TNCs, R&D activities of foreign subsidiaries could be considered as a major link between host country innovators and global R&D networks, serving as an important vehicle for the diffusion of new knowledge and technologies (Cantwell and Iammarino, 1998).

Though it is recognised even by critical authors (see Katz, 2000) that TNC subsidiaries can play an important role regarding technology diffusion in their host countries, we do not know much on their real impact. In a recent contribution, Narula (2004, p. 8) comments: ‘while the potential for MNC-related spillovers are clear, as are the opportunities for industrial upgrading therefrom, it is increasingly acknowledged that the nature, level and extent of the benefits vary considerably’. He points out two conditions for reaping benefits from TNCs: first, spillover must exist and second, domestic economic actors must possess the appropriate level of absorptive capacity.

According to Lam (2003), benefits from TNC subsidiaries can vary according to their country of origin. Based on case studies of US and Japanese subsidiaries located in the UK, the author found that Japanese-owned subsidiaries behave differently from US-owned subsidiaries as far as local networking is concerned. Different propensities to establish local networks could be rooted in distinct institutional characteristics of the TNC’s home countries (Doremus et al., 1998).

Castellani and Zanfei (2002) argue that the creation of links between subsidiaries and local firms depends on the experience of subsidiaries, this is, the number of years they have been present in their host country. Similarly, Narula and Zanfei (2003, p. 12) complement that the integration of TNCs in host countries is costly and time-consuming: ‘even where the host location is potentially superior to the home location - and where previous experience exists in terms of other value adding activities - the high costs of becoming familiar with, and integrating into a new location may be prohibitive’. As a consequence of this, subsidiary management tends to carefully evaluate the relationship between the costs of local networking and the expected benefits in terms of access to new knowledge and technologies.

Specific characteristics of some developing or newly industrialising countries may also hamper building links between companies and research institutes or universities. For instance, Dagnino (2002) remarks that the Latin American scientific community has internalised the values and quality standards of industrialised countries’ scientific communities; and, consequently, the Latin American research institutions do not match local demand but rather the technological demands of industrialised countries. Though this may be

true, TNC subsidiaries are probably less affected by this 'mismatch' than local companies for two reasons: first, TNC subsidiaries are generally working in accordance with the technological standards of their industrialised countries of origin; second, some of them are so-called 'export platforms' which develop and produce for world markets. Indeed, empirical data from Brazil suggest that TNC subsidiaries interact more with local universities and research institutes than Brazilian owned companies do (Costa and Queiroz, 2002).

Empirical findings in other latecomer countries (India, Ireland, Israel) suggest that the timing of entry may have an influence on the occurrence of linkages and spillovers; in particular, entry of TNCs before the development of a domestic industry does not seem to benefit spill-overs since there are only few potential partners of local origin and, in addition, the development of a domestic industry may even be hampered (Giarratana, Pagana, Torrissi, 2004).

However, TNC subsidiaries develop over time and new generations of locally recruited managers often have a personal interest to build up internal R&D capabilities and to establish links with their country's institutions. Subsidiary management may actively try to enhance their importance within the TNC and to assume more sophisticated roles, different from mere implementers of technologies developed elsewhere (Birkinshaw, 1998). Hence, the subsidiary role in R&D might be an important variable in order to explain why some subsidiaries create strong links with local partners while others do not.

2.2 Strategic Roles of TNC Subsidiaries

Headquarters can attribute different roles to its subsidiaries. 'Local roles' refer to activities such as product adaptation or local original R&D and focus on the host country market. 'Global roles' imply that a subsidiary contributes to global R&D programmes because of their distinctive knowledge and leading technological capabilities within the MNC. They are sometimes called 'centres of excellence' or 'centres of competence'. Subsidiaries may also be responsible for the development of entire product families for world markets. These 'global subsidiary mandate' (Roth and Morrison 1992) or 'world mandate' (Feinberg 2000) generally coordinate strategy and related value chain activities (R&D, production, logistics, and marketing) for a specific product family.

Indeed, previous research suggests that subsidiaries with global roles in R&D are likely to have more links with external sources of competence in the host country (Frost, Birkinshaw, Ensign, 2002), particularly as far as buyer-supplier relationships are concerned (Andersson and Forsgren, 2000). Local links help subsidiaries to identify and absorb specific external knowledge that can become important for the whole TNC and thus justify global roles such as 'centres of excellence' (Holm and Pedersen, 2000). They tend to be closely connected to host country science and technology systems (Reddy, 1997; Nobel and Birkinshaw, 1998). Moreover, it has been argued that subsidiaries with global R&D roles and higher decision-making autonomy can contribute positively to host country Innovation Systems (Meyer-Krahmer and Reger, 1999).

One may contend that these contributions are not fully applicable to developing or newly industrialising countries. Yet, drawing on the technological capability literature (which mainly focuses developing countries), we may come to a similar conclusion as above-mentioned contributions. Following Lall (1992), Bell and Pavitt (1995), a high technological (innovative) capability is associated with Science and Technology (S&T) links. As R&D units with global roles presuppose high technological capabilities in order to compete on world markets, we may deduce that R&D units of TNC subsidiaries located in developing countries should also have strong S&T links.

Nevertheless, it is seldom recognised that there may be specific advantages or disadvantages in developing countries which could challenge above-mentioned logic. The discussion of empirical data from an innovation survey and our case examples is meant to cast some light on the actual importance of local links for TNC subsidiaries located in Brazil. Before that, we need to specify our analytical framework.

3 Analytical Framework

Up to this moment, we have dealt with ‘interaction’ or ‘links’ as if all of them were similar in nature. However, links may be characterised as unidirectional or bi-directional, short-term or long-term relationships, frequent or sporadic. Generically speaking, interaction between TNC subsidiaries and local partners may involve cooperative R&D activities or outsourcing contracts. While the former are bi-directional, of longer duration and may offer valuable learning opportunities for both partners, outsourcing contracts often focus on technological services which can be provided by several substitutable partners. Moreover, outsourcing is frequently limited to exchange know how hidden in ‘black boxes’, whereas cooperative R&D links are more adequate to absorb technical or scientific knowledge.

While technical knowledge is tacit, embedded into specific organisational, cultural and institutional contexts, scientific knowledge is explicit and universal. Technical knowledge may be acquired using a trial and error ‘strategy’, whereas the creation of scientific knowledge requires methods and logical deduction (Marglin, 1990, pp. 223). Combining or integrating scientific and technical knowledge generates technology; in other words,

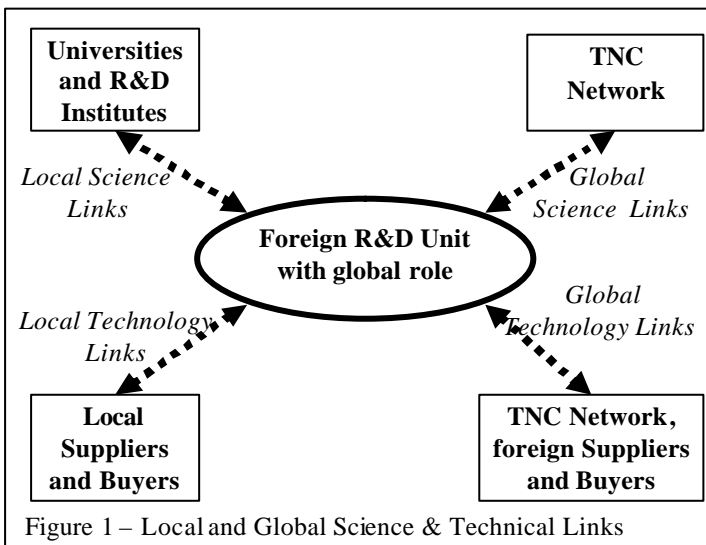


Figure 1 – Local and Global Science & Technical Links

technology is technical knowledge made explicit using scientific methods or scientific knowledge converted into practical procedures. For this reason, technological progress cannot be solely derived from science (Zawislak, 1996). Putting it differently, ‘strong science provides tools for problem solving, but usually in itself does not solve practical problems.’ (Nelson, 2004, p. 458).

Carrying this logic a bit further, we may pose that companies which are able to integrate scientific and technical knowledge under ‘one

roof’ are in a position to innovate creating new technologies. Both types of knowledge may be absorbed from cooperation partners; if these partnerships also permit to acquire technical knowledge, we call them ‘technology links’; if they are focused on scientific knowledge, we call them ‘science links’. In general, science links refer to cooperation between companies and research institutes or universities, whereas technology links refer to cooperation in product development with buyers and suppliers. These links are fundamental elements of innovation systems (see, for instance, Lundvall, 1988, on user-producer relationships and Nelson, 1988, on the role of universities).

Accordingly, TNC subsidiaries which are capable to carry out combinations of both types of knowledge are able to create new technologies. Subsidiaries may absorb these types of knowledge either from their mother company (headquarters or other subsidiaries) or from external partners such as universities, research institutes, suppliers or clients. If a subsidiary

obtains scientific or technological knowledge via cooperative interactions with other TNC units, they are henceforward called ‘global science links’ and ‘global technology links’ respectively. If cooperative interaction with local, host country partners takes place, we use the terms ‘local science links’ and ‘local technology links’ respectively. Hence, subsidiaries’ R&D units can dispose over four types of links: 1) global science links with TNC research laboratories and foreign based universities and R&D institutes, 2) global technology links with TNC sister subsidiaries and foreign based external suppliers and buyers, 3) local science links with host country universities and R&D institutes and 4) local technology links with host country suppliers and buyers (see Figure 1).

The link between host country innovation systems and international R&D networks or other countries’ innovation systems can be provided precisely by TNC subsidiaries’ R&D units[†]. In line with previous research (Gupta and Govindarajan, 1991; Holm and Pedersen, 2000), subsidiaries with global R&D roles tend to have strong science and technology links with sister subsidiaries, access state-of-the-art input worldwide and develop *new* knowledge or technologies. Therefore, they seem to be best positioned to create ‘a bridge’ between the host country innovation system and international R&D networks. This is why we restrict the focus of this study on subsidiaries with global R&D roles.

Apart from the type of links we need to consider their strength. Strong links have high impacts on the subsidiaries’ R&D activities. For example, buyer or supplier links are strong when they cause adaptations to the subsidiaries’ product technology (Andersson and Forsgren, 2000) and when both partners learn from each other. We may then speak of cooperative interaction.

Having said this, R&D units with global roles can be organised in a matrix-type classification scheme (Figure 2): the matrix displays four types of R&D units according to the strength of their science or technology links with host country cooperation partners. If the R&D unit’s local links are weak (‘Absence of Local Integration’), then we may consider it an ‘island of excellence’: in this case opportunities for knowledge spill-overs to the host country innovation system are limited. If either local science or local technology links are strong, then the R&D unit’s local integration is incomplete and the potential for spill-overs is restricted to the diffusion of either science or technology related knowledge. If all local links are strong (see ‘Local S&T integration’ in Figure 2), then the ‘bridge’ between the host country and other countries’ innovation systems is likely to be quite effective. Hence, the TNC subsidiary probably benefits the host country innovation system, since the subsidiary masters the whole R&D process (from research to product development) being able to create new technologies; and, at the same time, local science and technology partners are exposed to global technological requirements which may spur them to catch up.

		Local Science Links	
		Strong	Weak
Local Technology Links	Strong	Local S&T Integration	Local Technology Integration
	Weak	Local Science Integration	Absence of Local Integration

Figure 2 - Classification of TNC subsidiaries’ R&D units

[†] This particular form to link up with international networks seems to have attracted less attention as recent publications on Latin American National Innovation Systems indicate (see for instance Ferranti et al., 2003, chapter 7).

4 Methodological Considerations

According to Carlsson et al. (2002), empirical studies on national systems of innovation use mainly static and aggregate data on the links among buyers and suppliers (users and producers), universities, research institutes, government agencies among others. An advantage of this approach is its capacity to portrait the overall condition of a particular country's innovation system. The characteristics of individual components of the system are less considered. This may be a disadvantage particularly in countries that do not possess a mature innovation system yet and which show a high diversity of companies: a few of them highly innovative and a big amount of small and medium sized enterprises (SMEs) with unsatisfactory innovative performance. Furthermore, aggregate data does not take account of individual TNC subsidiaries, particularly those with a solid track record in innovative activities and global roles in product development.

National Innovation Systems can be analysed using the micro, meso or macro level approach (OECD, 1999). While the scope of the micro level approach is the individual firm, the meso level approach extends the scope of analysis to clusters and the macro level approach to knowledge flows among different institutions of the economy. Specifically, the micro level approach 'focuses on the internal capabilities of the firm and on the links surrounding one or a few firms, and examines their knowledge relationships with other firms and with non-market institutions in the innovation system, with a view to identifying unsatisfactory links in the value chain' (OECD, 1999, p. 24).

For our analysis of TNC subsidiaries, we combine the micro level approach and a specific type of the macro level approach. The idea is to identify gaps regarding knowledge flows or links among organisations (micro-level) and dysfunctional relationships among institutions as far as knowledge flows are concerned. The combination of both approaches is useful here for two reasons. The macro level approach provides the context for a detailed micro level study. In particular, it may contribute to understand which sectoral and overall patterns regarding science and technology links exist; thus, the combination of both approaches can indicate to what extent specific case examples (micro level) comply with or differ from more general patterns. The case examples, in turn, can help to understand why science or technology related knowledge flows or links are present in one situation but not in another. Therefrom, we may gain useful insights for policy making.

Analysing particular elements of an innovation system can be helpful to understand what may be behind aggregate data as well as to gain insights about systemic failures and gaps in the system. From the perspective of the technological system approach, Carlsson et al. (2002) distinguishes three levels of analysis: technology, products and competence blocs. We opted for products as level of analysis as we are interested in the diffusion of knowledge related to product development. So we consider those elements of the system which participate in the development of a product or product family coordinated by a TNC subsidiary.

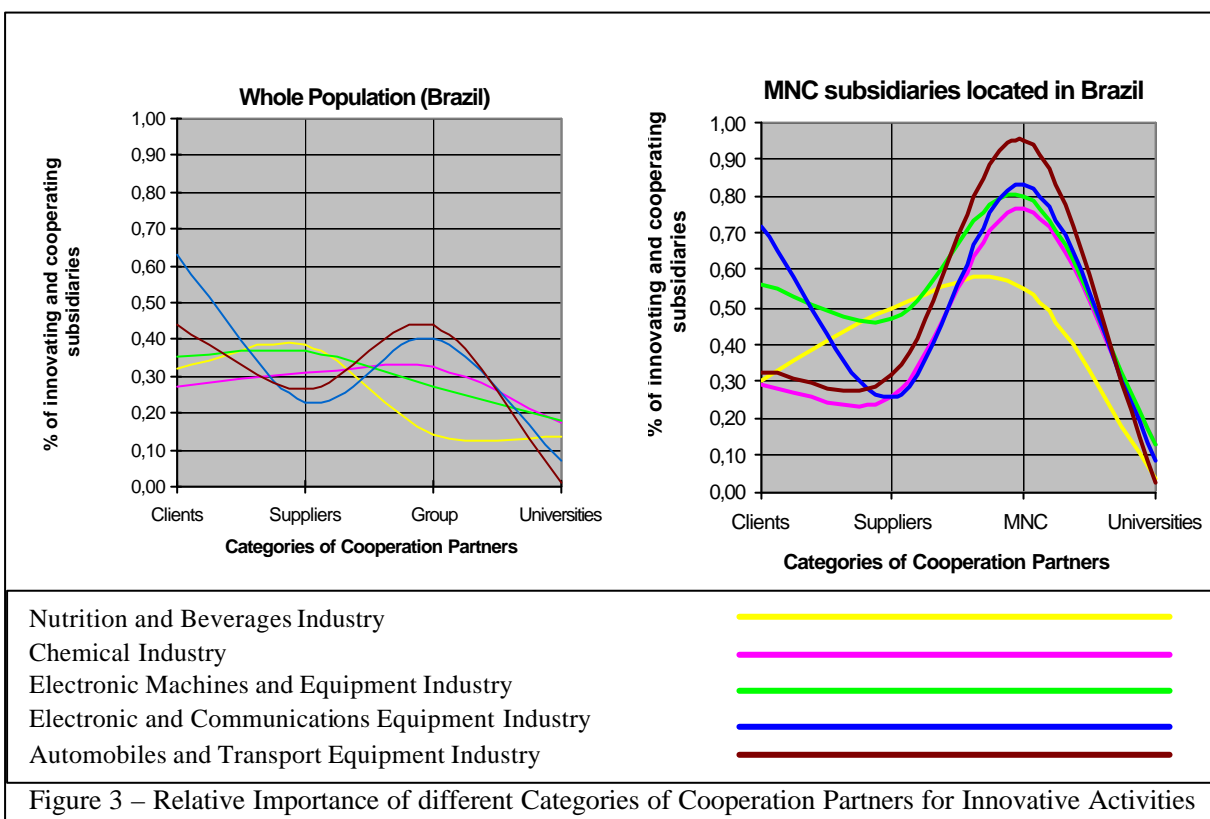
As regards links or knowledge flows, we differentiate between cooperation and outsourcing of product development related activities; because we assume that technological learning is more effective when different organisations cooperate.

Thus our approach focuses on a group of specific components of the system: the TNC subsidiary with product development activities and its direct (or first order) links with partner organisations. Correspondingly, TNC subsidiaries constitute interfaces between the host country innovation system and innovation systems of those countries where other TNC subsidiaries or partner organisations are located.

5 S&T Links of TNC subsidiaries in Brazil

In order to contextualise this study, a brief analysis of data from a major innovation survey (IBGE, 2002) provides us with an overview on links between TNC subsidiaries of five industrial sectors and host country partners such as suppliers, clients, universities and research institutes.

For this purpose, a subset of wholly and partially foreign-owned companies was extracted from the PINTEC database¹. The subset amounts to 1.348 manufacturing companies, 451 (33%) of which have relied on cooperation for their innovative activities from 1998 to 2000. Cooperation was defined as ‘active participation in R&D projects and other innovation projects with other organisations be it companies or institutions’ (IBGE, 2002, p. 20); subcontracting is not included in this definition. Respondents were asked to indicate whether a certain category of cooperation partners had “high”, “medium”, “low” or “no” importance for their innovative activities. In addition, they were asked whether the main partner organisation was located in Brazil or abroad.



We compared the relative importance of different categories of cooperation partners (suppliers, clients, other TNC units, universities and research institutes) for the subsidiaries’ innovative activities. For this purpose, we calculated the frequency of “high importance” cooperative relationships in each category of partners as a proportion of the total number of subsidiaries with cooperative relationships in a particular industrial sector. For instance, as 17 (around 50%) out of 35 subsidiaries in the nutrition and beverages sector indicated that the category of “suppliers” is highly important for their innovative activities, we may say that suppliers in this sector are far more relevant than in the chemicals sector where only 25 (or 26%) out of 97 TNC subsidiaries attributed high importance to cooperation with suppliers (see Figure 3).

In general, we may deduce from this data that other TNC units (headquarters or sister subsidiaries) are the main partners in R&D. Local universities and research institutes, however, are far less important than local clients and suppliers; less than 10% of innovating

and cooperating subsidiaries considered them as cooperation partners of high importance. A survey on the quality of university-industry interaction seems to be in line with IBGE's findings: most of interactions can be considered as outsourcing of technological services and less than 30% of all interactions can be considered R&D contracts (Ritter dos Santos, 2003). Correspondingly, a recent master thesis concluded that TNCs in the telecommunications industry have only low interest in cooperative agreements and see relationships with universities as a cheap form to carry out adaptations of their global products which are generally developed abroad (Sávio de Mecnas, 2003).

Differences according to industrial sectors are considerable. For instance, in the chemical and automotive industry, the importance of cooperation between subsidiaries located in Brazil and other TNC units is three times as high as cooperation between subsidiaries and suppliers or clients. Interestingly, in the electronics and communications equipment industry, cooperation with local clients is nearly as important as collaborations with other TNC units. In the chemicals as well as in the electronic machines and equipment industries, links with university and research institutes are most common.

We did the same exercise with respect to different 'sources of information' for innovative activities considering the importance of six information sources, internal R&D, other internal sources of information, other TNC units, suppliers, clients as well as universities and research institutes. The results tell the same story: universities and research institutes[‡] are the least relevant information sources which suggests a low propensity to create new technologies. Clients and suppliers[§] are far more important information sources than universities and research institutes which seems to confirm that most of TNC subsidiaries carry out mainly adaptive R&D.

In brief, data seems to confirm that local science links are probably a rare exception which may indicate a 'gap' in the innovation system. Local technology links, however, seem to be much more common. In addition, other TNC units predominate as cooperation partners and information sources for innovative activities. However, this broad picture does not tell us anything about the group of TNC subsidiaries with global roles in R&D; the next section is exclusively dedicated to this group.

6 Case Examples

In order to illustrate our argument mentioned in the introduction, all four types of subsidiaries with global R&D responsibilities (and their respective science and technology links) will be discussed in the light of several case examples of TNC subsidiaries located in Brazil. They belong to the electronic machines and equipment industry, communications equipment industry as well as the automobiles and transport equipment industry. Particular attention will be paid to the way these subsidiaries articulate their local and global links. In addition to personal interviews, secondary information from business newspapers as well as congress papers and dissertations were used in order to complement interview data. Data collection and analysis was carried out between 2001 and 2003. The combined analysis of these factors reveals some characteristics of the links which TNC R&D units have or have not established with the Brazilian innovation system.

6.1 Local Science and Technology Integration

Siemens' telecommunications R&D unit is one of 9 centres of competence for small and medium-sized private enterprise switches and contributes to global software development

[‡] They are highly important sources of information for less than 10% of TNC subsidiaries.

[§] They are highly important information sources for 30-40% of TNC subsidiaries.

programs managed by headquarters. It is also one out of 11 regional development centres and thus responsible for the development of a specific hardware module of a new generation network (NGN) switch. Regarding mobile telephony, Siemens Brazil is implementing a centre of competence for cellular phone desktop emulation. Siemens owns four R&D centres in Brazil and maintains a corporate technology department. The latter's responsibilities are technology planning and management of R&D activities, building up and maintaining partnerships with local institutions, technology transfer, patenting, participating in government bodies for technical norms and regulations.

5.1.1 Global Links

By definition, centres of competence participate in global R&D projects which are coordinated by headquarters. Each centre specialises in a particular technological niche where it has achieved world standard and shares its knowledge with sister centres and headquarters. In other words, there are strong technology links between the centre and sister centres all over the world. Transfer of tacit knowledge is carried out by frequent exchange of engineers. Part of the centre's specific knowledge has been accumulated assigning technical staff to projects at headquarters.

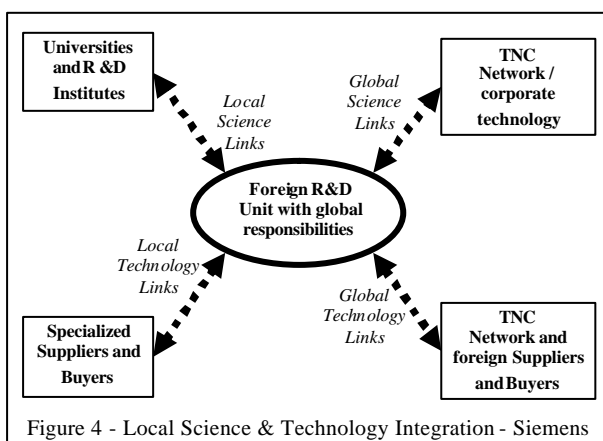
As for science links, most of applied research is done at headquarters which transfers scientific knowledge to its subsidiaries. But the Brazilian subsidiary also contributes to corporate technology using its science links with local universities and research institutes.

5.1.2 Local Links

Tax incentives ('Informatics Law') for investments in R&D partnerships have been used to build up a strong network of more than 20 local R&D partners (universities and R&D institutes). The partners have received heavy investments in equipment and training from Siemens during the boom years of the telecommunications industry, from the mid 1990s until 2001. For instance, partner R&D institutes close to the plant in Curitiba received more than US\$ 15 million in that time. This external R&D infra-structure is recognised by headquarters and was a crucial factor when centres of competence were assigned.

In response to increasing cost pressures from 2002 onwards, Siemens' Brazilian R&D unit was required to reduce internal headcounts and transferred part of its engineers to external partners. Hence, many employees of these partner organisations are still highly familiar with Siemens' corporate culture. Thus local links have become increasingly important to maintain the critical mass essential for participating in global R&D projects.

As for technology links with local clients, it is worth to mention that Siemens Brazil is supplier of the main telecom carriers and needs to solve their problems with locally developed technology. Recently, Siemens implemented together with CPqD and the Brazilian owned company Trópico the first new generation network (NGN) in Latin America for Telefonica's subsidiary. In addition, there are some specific demands on the Brazilian market such as public switches that emulate private telephone switches, intelligent technology to validate whether cloned phone cards or falsified money is used and other anti-fraud systems. According to a Siemens staff member, some of these niche products have chances to get adopted globally. Thus, we may say, links with local partners seem to have a considerable influence on product



technology.

Big companies such as TNCs are in a position to improve innovation systems. There are incipient signals that some TNCs like Siemens are trying to implement a strategy, called 'voice-strategy' (Narula and Zanfei, 2003), targeting particularly the weak and often missing link between universities and industry in innovation systems suffering from a sort of 'systemic inertia'. The recent implementation of a web-based university-Siemens interface, ("Portal de Tecnologias") tries to capture the supply of technological solutions which can be provided by research institutes, universities or incubators via an Extranet in order to match it with internal demand which is articulated via the Intranet of the company. During the first three months, more than 100 technology partners have already registered, more than 10 projects have been started, and three of them attend directly technological demands of headquarters (Cyrino, 2004). This example shows how the Brazilian innovation system is becoming interconnected with global networks.

What explains this initiative given the fact that establishing and maintaining links is expensive and time-consuming (Narula and Zanfei, 2003), particularly when resources become more and more limited? Siemens Brazil is one of the very few TNCs in Brazil which run a Corporate Technology department. Thus, human (time) resources are available in order to strengthen relationships with local partners and to develop an own strategy for technological upgrading in several business units. The corporate technology department can be justified since the company has to invest into R&D being a beneficiary of the informatics law. Corporate Technology Brazil is tightly linked to Siemens' global Corporate Technology department and knowledge management activities.

In addition, corporate technology staff participates in government commissions and international (Latin American) bodies that decide on technical norms and regulations. Thus Siemens lobbied for the adoption of a European cellular phone standard (GSM). This was possible due to the company's long history in the country and strong commitment to technological development.

5.1.3 Implications

With respect to science and technology links, the communication technology division of Siemens Brazil seems to be quite well integrated both with local and with corporate partners. Being a full fledged technology creator seems to benefit the subsidiary's position within the TNC as host of several centres of competence. With regard to the Brazilian innovation system, local R&D partners seem to benefit since they can integrate themselves into global R&D networks using the '*Portal de Tecnologias*' interface. In addition, this interface permits transfer of technology from research to industry, helping to generate new sources of income and bridging the divide between university, research institutes and industry. Thus, this example seems to indicate that the current innovative capacity of the Brazilian sectoral innovation system in telecommunications is not that negative as it appears which seems to support Mani's (2004) argument. However, a single company does not tell the whole story; we should therefore discuss another example of the same sector.

6.2 Local Science Integration

Ericsson is an example which is partly integrated into the innovation system. Ericsson has established its first Brazil-based R&D centre for switching technology in the beginning of the 1970s. However, as hardware is more and more turning into a commodity, technological change accelerated and markets were opened to foreign competition, Ericsson discontinued its Brazilian hardware development activities. Today, proprietary software is increasingly important to gain a competitive edge and the new R&D centre in Indaiatuba, São Paulo State,

is exclusively focused on software development. Ericsson's software development unit owes its current size (around 250 employees in 2003) to tax incentives ('Informatics Law') corresponding to approximately R\$ 62 million (roughly US\$ 20 million). However, during the boom year 2001, tax incentives were considerably higher and resulted in R&D investments close to R\$ 150 million (roughly US\$ 70 million). The unit has software development responsibilities for Ericsson's global telecom switching platform AXE and is also considered a centre of excellence (or competence) in billing systems.

5.2.1 Global Links

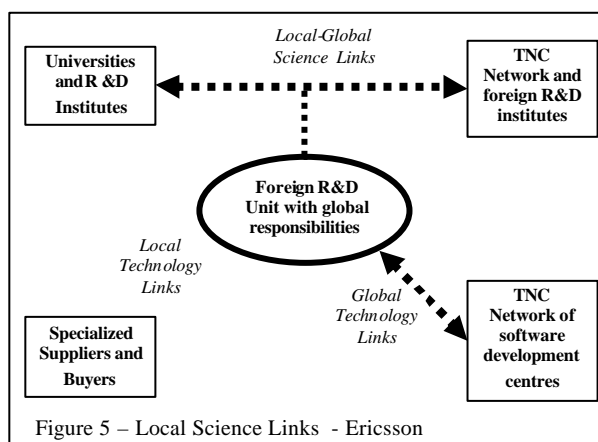
Coordination of the company's global R&D activities is highly centralised at headquarters and R&D projects are attributed according to performance indicators and the specific competences of each centre. Thus, different subsidiaries assign projects to different R&D centres according to the latter's specific competences and some projects are carried out by globally dispersed virtual R&D teams. Ericsson Brazil participates in global development since the 1990s and also transfers technology to other subsidiaries.

There are no science-related links between the Brazilian R&D centre and the other units of the corporation, but Ericsson Brazil intermediates applied research contracts between local universities or research institutes and Ericsson's corporate R&D. In other words, Ericsson Brazil generally does not use local research output for its short-term software development projects which are unrelated to medium and long-term research projects.

5.2.2 Local Links

In order to enjoy tax incentives (Informatics Law), Ericsson is supposed to invest a certain percentage of turnover in research partnerships with local universities and R&D institutes. Currently, the subsidiary maintains partnerships in practically all major regions of the country covering areas such as optical components and photonics, optical systems and networks, optical amplification, third generation mobile phones, wireless networks, intelligent antennas, signal and voice processing.

One of these partnerships has been realised with the Institute of Physics of the Federal University of Rio Grande do Sul. It is the first partnership of this kind for the institute which used to carry out exclusively basic research. The project started in 2001 and involved investments in sputtering equipment, scholarships for several PhDs, PhD and MSc students as well as other expenses (journeys, consumption of materials, etc.). These investments and other payments constitute the main counterpart of Ericsson Brazil in the project. It is worth to mention that several other R&D labs participate in this project, one of them is the Catholic University of Rio de Janeiro (PUC-RJ), ACREO, a Sweden-based private R&D institute, and Ericsson's corporate R&D. Hence, we may say that this form of partnership articulates several actors of the Brazilian innovation system with several actors of the Swedish innovation system. This particular form of cooperation seems to pioneer the linking up of Brazilian applied research with foreign R&D



networks, a model which seems to be imitated by several other TNCs. In this sense, the project contributes to the university research infra-structure and helps to qualify Brazilian researchers.

The potential to maintain technology links in product development with local partners has been curbed because of two strategic changes: first, since switching equipment and other hardware have become global products, hardware development in Brazil has been discontinued and the opportunities for buyer-supplier partnerships in product development vanished. Second, since a growing share of hardware has transformed into commodities, their production is increasingly outsourced to turn-key manufacturers such as Flextronics or Solectron.

5.1.4 Implications

This example shows a remarkable form of science integration between local universities and organisations in foreign countries (headquarters and research institute), but no science integration between local partners and the TNC subsidiary. The scientific knowledge which is sourced locally is not related to the software development activities of the R&D centre. Links with suppliers have become redundant. Thus, the subsidiary's R&D centre is somewhat decoupled from the innovation system. In addition, science links with local universities and research institutes do not seem to be of high strategic importance for the company since even headquarters has discontinued various areas of hardware development due to technological change and the recent crisis in the telecommunications industry. The focus of many R&D projects has also changed, giving priority to reducing time-to-market and product costs while reducing investments in pathbreaking new technologies. As a consequence of this, it is open to question whether the results of the mentioned applied research projects will have a chance to become future products of the TNC.

Hence, we may conclude that, on the one hand, Ericsson's projects have been contributing to link up Brazilian universities and research institutes among each other and with R&D in other countries. In addition, we observed that it is contributing to a cultural re-orientation in public universities where applied research is seen as less meritorious compared to basic research and where university-industry interaction has little tradition. On the other hand, the missing interaction between the company's R&D centre and the Brazilian innovation system makes it vulnerable both to strategic reorientation on the corporate level and to oscillations regarding tax incentives (Informatics Law) since opportunities for technology generation combining scientific and technological knowledge are limited. This has been evidenced by a considerable reduction of R&D investments between 2001 and 2003.

6.3 Local Technology Integration

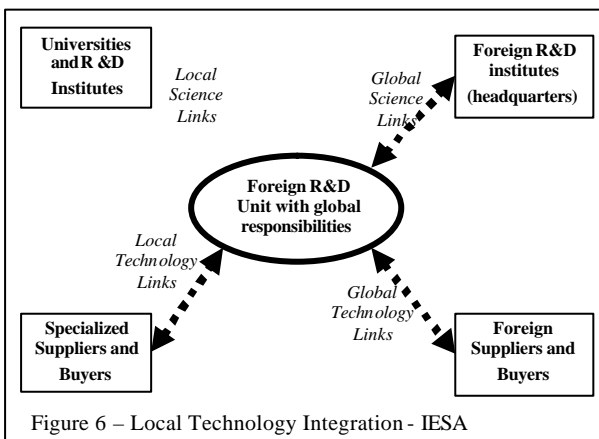
International Engines South America produces and develops high speed Diesel Engines in Brazil. The company considers its Diesel engines to be global products which need to be in line with environmental regulations in its most demanding markets, such as the US and Europe. The Brazilian subsidiary is a Global Subsidiary Mandate for high speed diesel engines due to its unrivalled competence within the TNC. There are several other companies which develop diesel engines in Brazil, such MWM, Cummins and DaimlerChrysler, but International Engines and MWM are the only two system integrators which develop completely new projects for electronic diesel engines. After International Engines bought the formerly Brazilian owned company in 2001, a high degree of operational autonomy has been preserved as its new Brazilian subsidiary complements very well the product range of International Engines' US-based activities. Until its Brazilian venture, International Engines' production and R&D activities had been confined to the US.

5.3.1 Global Links

Since the company has become a TNC only a few years ago, it does not surprise that integration between the Brazilian R&D centre located in São Bernardo dos Campos, São Paulo State, and corporate R&D in Melrose Park, USA, are only recently being closer coordinated and ‘knowledge exchange is still not yet organised in a systematic manner’; when knowledge exchange occurs, though, it is frequently a Brazilian initiative. A senior manager of the company even claimed that the Brazilian company ‘has always been more internationalised than the US-based mother company as far as cooperation with foreign partners is concerned’.

The somewhat weak link between US and Brazil-based R&D and the strong links between Brazil-based R&D and foreign technology partners can be explained looking some years back into the company’s history. Brazilian operations date back to the late 1950s when British Perkins started to produce engines in São Bernardo. In 1984, a Brazilian financial conglomerate (Iochpe Group) took over the Perkins subsidiary and branded it Maxion. In 1989, Maxion started to develop a medium speed diesel engine, using an existing engine platform. In 1994, pressed by a more hostile competitive environment after the reduction of import barriers, a technology transfer agreement with Rover laid the basis for the development of ‘high speed diesel engines’, a relatively new product even in Europe.

As a further consequence of this technology transfer agreement, Maxion established partnerships with independent R&D institutes specialised in engines technology in Austria and Germany (AVL, FEV). These institutes are world leaders and carry out science-based analyses for several engine developers.



In addition, Maxion strengthened partnerships with black box suppliers of high technology components. They account for a major share of development costs (around 70%) and their R&D activities are mostly foreign based. Hence, the São Paulo based R&D unit is a sort of systems integrator which works closely together with its main component suppliers and specialised technology partners based in different countries (mainly Europe and Brazil).

International Engines South America supplies motor vehicle assemblers in Brazil, Australia, Europe and mainly in the United States. Technology links with buyers (assemblers) involve testing of prototypes in new vehicles and help to refine product technology during the final stages of the product development process.

5.3.2 Local Links

Some of the black box suppliers as well as all manufacturing technology suppliers have R&D laboratories in Brazil. According to industry experts, ‘practically all types of suppliers needed in order to develop new engines are present in Brazil’. In other words, International Engines is integrated in an established cluster of specialised suppliers. This is a necessary prerequisite for the company’s success since ‘it does not exist any component on the store shelf’; valves, for instance, need to be adapted to the technical specifications of new engines. Geographic proximity (São Paulo State) facilitates personal contacts and helps to speed up product development. Yet, there are a variety of indispensable equipments which are not available in Brazil and ‘day-to-day business does not leave much time for identifying and negotiating with new technology partners’.

Interaction with local universities and research institutes is generally limited to outsourcing of particular tasks such as tests and analyses. Conjoint R&D, however, is currently not being practised. 'We already did some projects with some leading universities, but the results were not satisfactory'. According to a R&D manager of the company, problems of university-industry interaction are rooted in different cultures and time horizons: 'the universities are not as agile as we are'. Furthermore, the technological knowledge is regarded as extremely specific and R&D management believes that local universities simply do not possess it. With regard to the staff of the R&D centre, an empirical culture, quite remote from academic milieu seems to prevail: 'I tried to provide incentives for my staff to get enrolled into MSc studies, but management did not show any interest in this initiative yet'. But some changes are under way since Maxion was taken over by International Engines: in 2001 the Brazil-based R&D centre started to implement a property rights policy.

5.1.5 Implications

We may conclude that International Engines' Brazilian R&D centre is technologically quite independent from headquarters and owns even several unique technological advantages, since it has been able to adopt best practices in product development from several companies (Perkins, Rover, International Engines and Maxion).

Being a system integrator, its contribution to the innovation system is quite high, because the R&D centre articulates world standard demands in component technology and, thus, forces its local suppliers to upgrade. Regarding other TNC supplier companies, International Engines provides an argument for them to maintain R&D activities in Brazil which cannot be taken for granted in times where R&D investments are curbed due to cost pressures.

However, missing local science links could become an obstacle for the developmental dynamics of this cluster, as local universities and research institutes remain cut off from global innovation dynamics in the engine industry.

6.4 Absence of Local Integration

SpringerCarrier, an air-conditioning manufacturer, obtained its first global responsibility as a design centre for product platforms of wall-rested air-conditioners at the end of the 1990s. After heavy cost cuts in 2001, the R&D unit is again on a course of growth and gained its second global responsibility in 2003 for the development of a split air-conditioners family. Currently, the Brazil-based unit is the only one in Latin America with global product development responsibilities and belongs to a small elite of 12 lead design centres worldwide. Product development is centrally coordinated by headquarters which runs a 40 global R&D projects simultaneously; two of them were assigned to the Brazilian unit.

5.4.1 Global Links

Research is highly centralized in the United Technologies Research Centre (UTRC), located in East Hartford, US. The centre employs around 160 PhDs and hosts the systems and the components department; while the systems department establishes the general specifications each component of a system needs to comply with, the components department innovates on the basis of these specifications. For instance, research activities are focused on new materials such as special plastics for highly resistant boxes for air conditioners. Other completely new technologies focus on revolutionizing energy consumption and environmental impacts of refrigeration systems. Following technology push logic, UTRC provides science based input for the 21 design centres in the air-conditioning business.

Coordinated R&D projects centrally, headquarters is able to identify best practices among their lead design centres and urges those centres lagging behind to adopt solutions developed elsewhere in the company. For instance, a project being presently developed in Brazil faced difficulties and did not get through a specific gate of the product development process which is strictly controlled by headquarters. In order to remedy this, the Brazilian lead design centre contracted consultants from a local university and from the US - and managed to pass the gate. Today, the improvements made in Brazil have become reference for other design centres of the TNC.

Indeed, this type of centrally administered worldwide learning promotes the exchange of technological knowledge among the centres. ‘We used the basis developed in the US, we improved it and passed it on to others. Thus each lead design centre uses the basis of another and adds something in order to reach a higher level of technical expertise’.

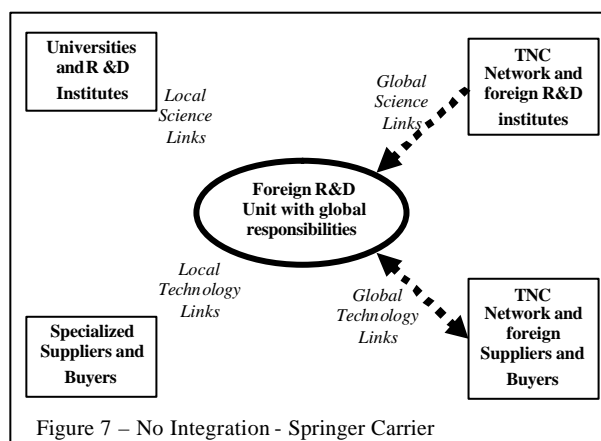
5.4.2 Local Links

Local links with host country partners, however, do not impact SpringerCarrier’s product technology. Most of the parts are provided by local suppliers, but they provide standardised low technology input; consequently they can be switched easily. Though relationships with local universities and technology centres exist, they are limited to outsourcing of particular product development tasks. Outsourcing is highly important in order to raise the efficiency of the product development process and the company would like to increase the share of outsourced activities. However, this is not possible yet, because there seems to be a lack of adequate partners.

Conjoint research activities are not yet done together with external partners. A potential project in electrical engineering exists and also a partner: a local public university institute headed by a former UTRC researcher who knows the company quite well. Authorization and funding by headquarters is a necessary condition but not an impediment any longer, since the firm policy has changed and tends to favour sourcing scientific and technological knowledge from low cost countries. So what explains that science links have not yet been created in Brazil, a low-cost country with considerable R&D capacity at public universities?

One reason is the poor tradition of university-industry partnerships in R&D in Brazil as well as the notorious cultural divide between industry public universities; the latter often tend to privilege basic research while speed, agility and applicability counts most in private companies. In this particular case, what seems to be missing is time to build a working interface between the TNC subsidiary and the local university since staff is exposed to high performance and time pressures which do not leave much time for organizing long-term relationships.

According to the director of the design centre, a solution would be contracting a PhD; however, incentives for contracting PhDs are missing. First of all, he perceives that the market for PhDs in electrical engineering is quite small. This perception coincides with other studies which attested that ‘mostly in engineering and other technical disciplines’ human capital is scarce (OECD, 2001, p. 31). Second, low wages are not attractive for highly qualified foreigners to work in Brazil. Third, wages for PhDs are currently not very competitive compared to university wages taking into account that universities permit researchers to



manage their time much more flexible being exposed to less time pressure. Fourth, the Brazilian subsidiary does not have a career plan for PhDs.

5.1.6 Implications

In sum, integration with the Brazilian innovation system does practically not exist and SpringerCarrier seems to train more human capital for the market than the market is providing for them. So, what does explain the global role of the Brazilian centre?

The answer may be found in a favourable competitive position of the Brazilian centre compared to many of its 20 sister design centres. The lead design centres of Carrier Corporation compete for resources and project allocations. The technological capabilities and R&D infra-structure of competing centres are quite similar and projects are allocated to high performers in costs, lead time and quality. Sometimes, cost and time targets are very ambitious and going for projects requires strong entrepreneurial spirit. The Brazilian centre has strong cost advantages compared to its internal competitors in Korea, France, Italy, etc. For instance, cost advantages in Brazil have already permitted to attract projects from Italy and headquarters is currently evaluating the possibility to transfer even more projects from higher cost locations to the Brazilian centre.

In addition, the global responsibility is also based on internal technological know-how, which is tacit and therefore not easy to be transferred from one site to another. 'The standardised global product development process only says what to do, but it does not say how'. Other sites probably will face difficulties in catching up with the Brazilian centre as far as technical knowledge is concerned, since the Brazilian engineers have accumulated more years of product development experience and now possess a solid stock of tacit knowledge.

However, these advantages will probably be challenged within a few years by China and India-based design centres, since both countries have low cost advantages, competitive university research and highly qualified staff, some of them PhDs: it is 'much easier to find highly qualified staff in China than in Brazil' and interaction between universities and companies is also much stronger there. The director of the Brazilian centre felt 'excited when seeing such well-equipped university laboratories' on a recent visit to China. As a consequence of this, headquarters is currently enhancing R&D capabilities in China which reflects the rising strategic importance of the latter country within the TNC. In other words, the missing integration between the design centre and the Brazilian innovation system may become an obstacle to its future development.

7 Conclusions

As the four case examples suggest, there is some evidence for our argument stated in the introduction: contrary to what can be concluded from previous research, R&D centres with global roles in product development do not necessarily possess technology or science related cooperative links with host country partners be it buyers, supplier, research institutes or universities. Other factors such as tax incentives, cost advantages and accumulated tacit or technical knowledge within the subsidiary seem to explain global roles in those cases where local links are absent. Hence, subsidiaries with global roles may well constitute 'islands of excellence' and not necessarily contribute to the host country innovation system via interactive learning processes and the exchange of different kinds of knowledge. This finding is distinct from previous research and seems to suggest an answer to our research question of whether TNC subsidiaries contribute to host country innovation systems: they may, but the extent of their contribution depends on the strength of their technology and science related links with local and global partner organisations.

However, this analysis focused cooperative links and thus ignores other forms of direct interaction with host country partners. As signalled before, outsourcing of R&D related work has gained more and more importance since it helps companies to keep headcounts low and to respond more flexibly to market or technological uncertainty while maintaining innovation capacities. For this reason, many TNC subsidiaries tend to outsource routine analyses, prototyping and testing activities of new product development projects and keep concept development and design activities in-house. Some TNC subsidiaries such as the telecommunications unit of Siemens even contract design and concept development from external partners^{**}.

These types of outsourcing links have become possible because of a solid laboratory infra-structure and qualified staff in Brazilian research institutes and universities. They benefit obtaining access to external financial resources to cover their laboratory expenses and by being exposed to highly demanding quality and time-to-market requirements. Thus, TNCs can take advantage of local S&T infra-structure but without getting involved in cooperative R&D links. Apparently, innovation surveys, such as PINTEC, do not seem to fully take account of this type of link.

Essentially, since TNC subsidiaries may interact with one or more innovation systems to different degrees, they may also function as a feedback-mechanism regarding the host country innovation system. If a TNC subsidiary with a global role in product development is only loosely or not at all linked to the host country innovation system, then this might be an indication of a system failure or a gap in the system: a highly competitive R&D unit might not find adequate counterparts in its host country innovation system and therefore abstain from building linkages.

These considerations should suffice in order to show that Science and Technology policy needs to target distinct groups of TNC subsidiaries according to the type and strength of links they already maintain with local partner organisations taking into account the characteristics of the underlying technologies. Subsidiaries with strong technology and science links should be invited to diffuse their best practises giving them a frontrunner role in the process of improving the innovation system. In addition, specific policy mechanisms should strengthen R&D centres' technology and science links in order to increase the benefits of TNC subsidiaries for host country innovation systems in the long run. In this context, more attention should be paid to the potential of outsourcing as a mechanism to promote innovation dynamics. Some countries have already implemented policies to strengthen links between domestic and foreign owned firms – an example is the 'National Linkage Programme' in Ireland, a country which has also relied on TNC subsidiaries in order to spur economic and technological development.

References

- ANDERSSON, U. and FORSGREN, M. In Search of Centre of Excellence: Network Embeddedness and Subsidiary Roles in Multinational Companies, *Management International Review*, Vol. 40, No. 4, p. 329-350, 2000
- BELL, M.; PAVITT, K. The Development of Technological Capabilities. Trade, technology and international competitiveness, Haque, I. (ed.), Washington (DC), The World Bank, 1995.

^{**} This finding is based on preliminary survey results. The survey is still in progress and is part of the author's PhD thesis.

- BIRKINSHAW, J. Corporate Entrepreneurship in Network Organizations: How subsidiary initiative drives internal market efficiency, *European Management Journal*, Vol. 16, No. 3, p. 355-364, 1998.
- CANTWELL, J. and IAMMARINO, S. Multinational Corporations and the Locations of Technological Innovation in the UK Regions, *Regional Science*, Vol. 34, No. 4, p. 317-332, 2000
- CARLSSON, B. (Ed.). *Technological Systems and Industrial Dynamics*. Boston, Kluwer, 1997.
- CARLSSON, B. et al. Innovation systems: analytical and methodological issues, *Research Policy*, Vol. 31, p. 233-245, 2002.
- CASTELLANI, D. and ZANFEI, A. Multinational experience and the creation of linkages with local firms - Evidence from the electronics industry, *Cambridge Journal of Economics*, Vol. 26, No. 1, 1-25, 2002
- COSTA, I.; QUEIROZ, S. Foreign direct investment and technological capabilities in Brazilian industry, *Research Policy*, Vol. 31, p. 1431–1443, 2002.
- CYRINO TERRA, J. O que ocorre quando uma multinacional vê além da tecnologia da sede. *Inova – Gestão e Tecnologia*, Vol. 11, No. 37, 2004.
- DAGNINO, R. A relação Pesquisa – Produção: em busca de um enfoque alternativo, *Revista Interamericana de Ciência, Tecnologia, Sociedade y Innovación*, n. 3, 2002.
- DOREMUS, P.; KELLER, W.; PAULY, L. and REICH, S. *The Myth of the Global Corporation*, Princeton, Princeton University Press, 1998
- DOZ, Y; SANTOS, J and WILLIAMSON, P. *From Global to Metanational: How companies win in the knowledge economy*. Boston, Harvard Business School Press, 2001.
- FEINBERG, S. Do World Product Mandates Really Matter? *Journal of International Business Studies*, 31, 1, 2000, pp. 155-167.
- FERRANTI et al. *Closing the Gap in Education and Technology*, Washington, The World Bank, 2003
- FROST, T., BIRKINSHAW, J. e ENSIGN, P. Centers of Excellence in Multinational Corporations. *Strategic Management Journal*, v. 23, p. 997-1018, 2002.
- GIARRATANA, PAGANA, TORRISI. The Role of Multinational Firms in the Evolution of the Software Industry in India, Ireland and Israel. Paper to be presented at the DRUID Summer Conference 2004, Elsinore, Denmark, 2004.
- HOLM, U. and PEDERSEN, T. *The Emergence of MNC Centers of Excellence – A subsidiary perspective*. London, McMillan Press, 2000.
- IBGE. *Pesquisa Industrial Inovação Tecnológica 2000 (PINTEC)*, Rio de Janeiro, Instituto Brasileiro de Geografia e Estatística (IBGE), 2002.
- KATZ, J. *Pasado y Presente del Comportamiento Tecnológico de América Latina*, Santiago, CEPAL, Serie Desarrollo Productivo no. 75, 2000.
- LALL, S. Technological capabilities and industrialization. *World Development*, Vol. 20, No. 2, p. 165-186, 1992.
- LAM, A. *Organisational Learning in Multinationals: R&D Networks of Japanese and U.S. MNEs in the U.K.*, DRUID Working Paper No 03-03. 2003.
- LUNDEVALL, B.A. Innovation as an interactive process: from user-producer interaction to the national system of innovation, in: DOSI, G., FREEMAN, C., NELSON, R., SILVERBERG, G., SOETE, L. *Technical Change and Economic Theory*, London: Pinter, 1988, p. 349-369.
- MANI, S. *Coping with Globalization - An analysis of innovation capability in Brazilian telecommunications equipment industry*, United Nations University, Maastricht, 2004.
- MARGLIN, S. A. *Losing Touch: The Cultural Conditions of Worker Accommodation and Resistance*. in: Marglin, A.F. & Marglin, S. *Domination Knowledge*. Oxford: Clarendon, 1990

MEYER-KRAHMER, F. and REGER, G. New Perspectives on the Innovation Strategies of Multinational Enterprises: Lessons for Technology Policy in Europe, *Research Policy*, Vol. 28, p. 751-776 1999.

NARULA, R. ; ZANFEI, A. Globalisation of Innovation: The Role of Multinational Enterprises, DRUID Working Paper No 03-15. 2003.

NARULA, R. Understanding Absorptive Capacities in an “Innovation Systems” Context: Consequences for Economic and Employment Growth, DRUID Working Paper No 04-02. 2004.

NELSON, R. Institutions supporting technical change in the United States. In: DOSI, G., FREEMAN, C., NELSON, R, SILVERBERG, G, SOETE, L. *Technical Change and Economic Theory*, London: Pinter, 1988, p. 309-329.

NELSON, Richard. The market economy, and the scientific commons, *Research Policy*, v. 33, p. 455–471, 2004.

NELSON, R. *National Innovation Systems*. New York, Oxford University Press, 1993.

NOBEL, R.; BIRKINSHAW, J. Innovation in multinational corporations: control and communication patterns in international R&D operations, *Strategic Management Journal*, v. 19, p. 479-496, 1998.

OECD. *Managing National Innovation Systems*, OECD, Paris, 1999.

OECD. *Using knowledge for development: the Brazilian experience*, OECD, Paris, 2001.

POWELL, W.; KOPUT, K. e SMITH-DOERR, LAUREL. Interorganizational Collaboration and the locus of innovation: networks of learning in biotechnology. *Administrative Science Quarterly*, Vol. 41, p. 116-145. 1996.

REDDY, P. New Trends in Globalisation of Corporate R&D and Implications for Innovation Capability in Host Countries: A survey from India, *World Development*, Vol. 25, No. 11, p. 1821-37, 1997

RITTER DOS SANTOS, M. E. *Escritórios de Assessoria Tecnológica e a Interação Universidade Empresa (EATs), Relatório Final*, Porto Alegre, 2003.

ROTH, K., MORRISON, A.J. Implementing global strategy: Characteristics of global subsidiary mandates, *Journal of International Business Studies*, 23, 4, 1992, pp. 715-736.

SÁVIO de MECENAS, D. *Os mecanismos de interface da cooperação empresa-institutos de pesquisa no setor de telecomunicações*. Dissertação de Mestrado, USP, 2003.

SOBEET. *O comportamento tecnológicos de empresas transnacionais no Brasil*, Carta da SOBEET, No. 14, 2000.

UNGER, K. Industry structure, technical change and microeconomic behaviour in LDCs. In: DOSI, G., FREEMAN, C., NELSON, R, SILVERBERG, G, SOETE, L. *Technical Change and Economic Theory*, London: Pinter, 1988, p. 480-495.

VELHO; SAENZ, R&D in the public and private sector in Brazil: complements or substitutes?, United Nations University, Institute for New Technologies, Maastricht, 2002.

YOUNG, S., HOOD, N. and PETERS, E. Multinational Enterprises and Regional Economic Development, *Regional Studies*, Vol. 28, No. 7, p. 657-677, 1994.

ZAWISLAK, P. A. *A Relação entre Conhecimento e Desenvolvimento: Essência do Progresso Técnico*, Análise, 1996.

ⁱ Note that IBGE did not provide a subset limited to wholly -owned subsidiaries only, for reasons of confidentiality.