The Interplay between Sectoral and National Innovation Systems as a Challenge to Human Resource Management: The Case of Software in Telecommunications R&D in Brazil

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Abstract This work employs the system of innovation approach in order to analyse how national and sectoral dimensions affect R&D human resource management in a developing country such as Brazil. It presents how recent transformations in the building blocks of the telecommunications sectoral system of innovation, as part of a larger ICT sector, drive the internationalisation of R&D activities and raise the importance of software-related activities in such process, opening up opportunities for players around the world to become part of global innovation networks. Then, it highlights the national features of Brazil, more specifically supply and cost of qualified labour and the availability of S&T institutes for R&D partnerships, in order to identify a set of positive and negative elements affecting the attractiveness of the country as a potential destination of R&D investment. The discussion brings some implications to human resource management in local firms. Local innovation managers should be proactive towards strengthening local links and developing capabilities in software-related technologies, in order not to lose the window of opportunity to become part of global innovation networks. As a suggestion, the paper sets ups an approach for building a framework for the identification of the science and technology fields that are more important for the development of human resources. In conclusion, such approach can be used not only for capability building but also for portfolio management, influencing the competitive landscape for R&D activities and place a national system, as in the case of Brazil, in a better position at the telecommunications sectoral system of innovation.
Key words sectoral system of innovation, ICT, developing countries, human resource management, R&D

1 Introduction

In the last decades, the internationalisation of innovation activities, a process previously restricted to marketing and production, has included R&D in it, drawing from the development of decentralized labs in subsidiaries of multinational companies and from international cooperation agreements between many different actors (OECD, 2004). More recently, the internationalisation of R&D has been marked by three features: its speed is increasing, it is spreading through a larger number of countries, including developing economies, and it is involving activities beyond the adaptation of technologies to local conditions (OECD, 2006). The result is the development of many global innovations networks (Ernst, 2005; OECD, 2006; Pearce, 2005) and the telecommunications sector, as an element of the larger ICT sector, is one of many that are joining this process (Fransman, 2002b; Rao, 1999).

Previous research has shown that in theory there might be beneficial spillovers from technological partnerships between indigenous firms and subsidiaries of multinational firms in the telecommunications sector, which help the development of local innovation capability inside transition economies, such as Brazil (Leal, 2006). The main argument was brought up around the hypothesis that the telecommunications sector represents a promising environment for the development of local clusters between firms. Empirical data corroborates this, especially in software-related knowledge networks, where private research institutes now emerge as network integrators in Brazil (Perini, 2006). And it is in software-related activities where potential opportunities for R&D labs in Brazil are clearer, as explained throughout this paper. Technological convergence and other transformations in the telecommunications sector (Fransman, 2002a and 2002b; Engelstad, 2000) have made software-related technologies pervasive in almost every commercial product or service and R&D activity (Cukier, 2005; TNO/IDADE, 2005; Goldstein and Hira, 2004).

As different nations compete for the attraction of foreign direct investment directed to technological activities, such as R&D (UNCTAD, 2004), it is important to understand how all these sectoral transformations interact with a nation’s capacity to attract such activities. This has been the focus of previous research (Leal, 2007), which intended to help policy makers direct their efforts at reducing existing gaps in the Brazilian national system of innovation. As such, that research intended to provide national policy-level approaches to enhance Brazilian competitiveness in terms of scope and amount of R&D activities undertaken in local labs of subsidiaries of multinational companies. On the other hand, there has been no effort in trying to provide an approach for firm-level policies that might help innovations managers in Brazil attract investment in R&D activities, both in multinational companies as well as in indigenous firms and research institutes. One step has been given in Leal (2008), which made an exercise for creating a framework for defining software-related technologies and prospecting future trends in human resource requirements.

The purpose of this paper is to go one step further by analysing how the changes in the telecommunications sector affect human resource management in local R&D labs in Brazil. Such effort is important for a nation that is so dependant of multinational companies and has lost much of its home-based technological assets in the telecommunications sector (Loural et al., 2006), which seems to provide a new window of opportunity for catching up in software-related technological activities and become a global player in innovation networks.

The model of analysis is based on the sectoral system of innovation (SSI) concept, defined as a "set of new and established products for specific uses, and a set of agents carrying out activities and market and non-market interactions for the creation, production and sale of those products" (Malerba, 2002). The study of industrial sectors using this approach allows an understanding of structure and boundaries of a sector – something extremely important in telecommunications, due to the technological convergence with other sectors – of the agents and their interactions, of the learning, innovation and production processes, of the transformation of sectors and factors at the base of the differential performance of firms and countries in a given sector. The approach proposed by Malerba draws from two research traditions. The first is the evolutionary tradition, with its dynamics in terms of learning, knowledge and capabilities. The second is systems tradition, more specifically innovation systems, in which links and networks constitute key elements of the innovation process.

The building blocks of a SSI are: knowledge and technologies; actors and networks; and institutions (Malerba, 2004). The second chapter discusses these blocks in the specific case of telecommunications suggesting they drive the internationalisation of innovation activities. It also provides a more detailed approach on changes at the knowledge and technologies of this SSI, which makes software development a key element in R&D activities. The third chapter suggests these changes at the building blocks of this SSI provide challenges for indigenous firms and research institutes in a given country, as well as local labs from multinational subsidiaries, to become a part of a global innovation network. The discussion in centred on software development as both a challenge and a window of opportunity for R&D labs in Brazil, providing detail of the national dimension of this SSI in this nation's specific case. The fourth chapter presents some implications for human resources management in R&D labs in Brazil.

2 Telecommunications Sectoral System of Innovation Background

The purpose of this chapter is to show how the evolution of some elements from the building blocks of this SSI not only provide potential but also drive the internationalisation of R&D activities, which in their turn would open a window of opportunity for indigenous firms and research institutes in a given country, as well as local labs from multinational subsidiaries, to become a part of sectoral global innovation networks, specially in software-related activities.

2.1 Internationalisation of R&D in the telecommunications sectoral system of innovation

R&D activities in the telecommunications sector are complex in its nature. As a large technological system (Hughes, 1989), telecommunications evolve according to more or less well-defined patterns at the same time as the sector as a whole can evolve and expand. The great amount of technological fields required for standardization of commercial products, together with the simultaneous internalisation of many of those fields into R&D management, provide evidence of the complexity of this kind of activity inside firms from this sector (Leal, 2007).

Additional elements, originated in recent transformations at the knowledge base of this sector, provide *stimuli* for decentralization of R&D activities and room for international players to become part of global innovation networks. These transformations affect other building blocks of this SSI, namely institutions and actors and networks, and are discussed below.

First of all, changes at the knowledge base derive from technological convergence between telecommunications and information technology (IT) related disciplines. Its reflection is felt in the role of international standardisation bodies and standardisation consortia, two sectoral institutions that foster the modularisation of R&D activities and demand interoperability between sub products obtained from each R&D team.

Technological convergence can be described by means of changes in the technological and learning regimes, which create a new model of innovation in the telecommunications sector (Fransman, 2002b). In this model, named “Infocommunications” by Fransman, interoperability between different networks is the key to the success of services proliferation, crystallizing the merge between “telecoms services and equipment, computers, software, semiconductors, the Internet, e-commerce, and some of the media”. Another way to describe this convergence is to consider it a merge between different paradigms – from telecommunication and computer communication – around the evolution of a new “research program” inside the relevant scientific community (Engelstad, 2000). While the tacit goal in the old R&D process in telecommunication is centralized control of the network infrastructure in the hands of the service provider (ibid, p. 7), in computer communication the goal is to assure connectivity between different equipment and applications (ibid, p. 8), both in hardware and software, something that can only be accomplished through their interoperability.

This technological convergence process has created growing specialization and, consequentially, modularisation of activities in the R&D process (Rao, 1999). This line of thought foresees the beginning of a larger trend towards disintegration of important segments of telecommunications R&D, along with the emergence of an independent software industry derived from the convergence of computing, telecommunications and imaging (Fransman, 2002b; Rao, 1999), and also with the rapid growth of technological alliances (Rao, 1999). This means significant parts of R&D have become divisible, leading to specialisation and division of work.

The modularisation of R&D activities in telecommunications is intimately related to the institutional requirement for standardization of interoperability interfaces in different technological artefacts that comprise the infrastructure of a communications network (Leiponen, 2006). IEEE (2008), a sectoral organism, defines interoperability as the “ability of a system or a product to work with other systems or products without special effort on the part of the customer. Interoperability is made possible by the implementation of standards”. The important role played by standardisation in this sector comes from the fact that countless products and services, developed in firms from many nations, have to interoperate, since they depend on the same physical network to communicate with each other. The way each firm dispute the preference of its own technologies in the development of a given standard is defined by the social fabric created jointly with those standardisation institutions amply accepted by the players in this sector. Here one can see how two building blocks of this SSI – institutions and actors and networks – coevolve and bring dynamics to it. Innovation regimes in telecommunications are established by many international cooperation organisations, or in other words by social networks around a given technology with great participation of researchers from the R&D units of industrial players (Godoe, 2000). Many studies sought to demonstrate the important role of technological standardisation for the development of the sector (Blind and Gauch, 2008; Leiponen, 2006; Godoe, 2000), such as International Telecommunication Union (ITU), European Telecommunications Standards Institute (ETSI), Telecommunications Industry Association (TIA), IEEE (Institute of Electrical and Electronics Engineers) and WiMAX Forum.

According to what was explained above, the role of international sectoral organisms, such as ITU, in technology standardisation process is of gathering different technologies in many hierarchical levels. Their goal is to modularise the standardization effort and to facilitate the cooperation between many collaborators for this job, among which are the R&D teams from sectoral firms. One result of this process is the modularisation of R&D activities being developed inside these very firms. Different R&D groups can work in different stages under a higher hierarchy system. In other words, each R&D team dedicates itself to one of the modules that comprise any given technological artefact. For example, one R&D team inside a firm can dedicate effort to a specific hardware needed in a subscriber card inside a telephony switch, meanwhile another group works in the software that will be embedded in that hardware. The concrete merge of the results from these two groups is possible exactly because of the interface standardisation process that allows the interoperability of different elements that conform a commercial product. Since different modules have to be interoperable, it is vital, in the same way, to have standardized communication interfaces between R&D teams. The formalisation of theses interfaces allow the disaggregation of different teams and creates potential for their geographical dispersion.

The discussion above provides elements to understand the potential for R&D labs in subsidiaries of multinational firms throughout the world to be included in global innovation networks inside the corporation. For independent indigenous companies and R&D institutes, the disintegration of R&D activities in the telecommunications industry also creates opportunities for technological partnerships and consequently the insertion of these firms in larger global innovation networks. Rao (1999, p. 89-91) argues that the growing number of technological alliances in telecommunications, and in software in general, is an empirical evidence of R&D modularisation. This trend has already occurred previously in computer industry (Cloodt, Hagedoorn e Roijakkers, 2006) and provides further empirical evidence for his thesis.

While the previous discussion presented elements that provide potential for the modularisation of R&D activities, which allow the geographical dispersion of these, there are additional elements that must be considered in order to explain the necessity for this process to happen in the first place: economic and regulatory liberalisation, competitive pressure and R&D management patterns.

The globalisation process is based on the growing liberalisation of commerce between nations since the 1990's, on international financial flows and on investment into developing countries, bringing reflexes not only in economics but also in cultural values (CEPAL, 2002) and in organisational models in firms, bringing up the "informationalism" spirit (Castells, 1999). The telecommunications sector is but one of many industrial sectors that took advantage of that process, especially in what regards foreign direct investment (FDI) and the expansion of multinational companies. This means that some of the drivers of the internationalisation of R&D in this sector is exogenous, fruit of the economic liberalisation happening worldwide.

Another driver, this one endogenous, is the regulatory liberalisation process. This factor, parallel to the former, accounted for the intensification of the internationalisation of innovation processes, the abolition of monopolies and the entrance of new actors in the sector (Fransman, 2002b). In this new post-regulatory liberalization scenario, competition for markets has become global. Commercial liberalisation policies have contributed to the globalisation of R&D in the last decades (UNCTAD, 2004, p. 8). The goal of nations is to participate and stimulate this globalisation process, and in order to do that they have improved their environment to host technological activities in subsidiaries of multinational companies. This has led to the creation of policies linked to the economical basis of R&D activities, such as the development of skills and capabilities, the enhancement of supplier networks, the improvement of infrastructure and the development of a science and technology *substratum* (ibid). In new technology intensive industries, such as telecommunications, the proximity to basic science makes attractive those countries that offer good supply of human capital to undertake R&D, even those with small industrial experience (UNCTAD, 2005b, p. 160).

Generic pressures coming from cost reduction and search for technological assets have its impact on the telecommunications sector. Liberalisation and technological progress intensified competition, leading firms to invest more in R&D at the same time they control their expenses (UNCTAD, 2005b, p. 160). Competitive pressures come from (i) highly technology dependant products and services, making technology an important factor in firm competitiveness, and (ii) from the inherent complexity of global competition, which has grown due to the existence of new and differentiated products and producers, shortening product life cycle. Both elements lead to another, which is the growth of R&D costs and the need to incorporate technological assets wherever they are. This element stimulates global mandates for products and R&D in global innovation networks around multinational companies. Such environment, more and more characterized by short life cycle technologies, forces firms to spread their R&D activities worldwide – a process inserted in the growing offshoring of services (LEAL et al., 2006) – both via FDI and technological partnerships or mergers and acquisitions. This new R&D localisation pattern is different from the previous one, in which competitive advantage of firms depended basically on domestic environment. This new offshoring trend is also accompanied by the growing participation of developing countries, especially from Asia, both in terms of R&D subsidiaries and FDI-related R&D (UNCTAD, 2004, p. 4-6), which is corroborated by research on the intentions related to R&D expansion to other countries (ibid, p. 7).

Finally, as an answer to the drivers mentioned in this section, changes in R&D organizational patterns have created conditions for the development of many different kinds of R&D units. Firstly, it is important to remark that in the present "Infocommunication" model, R&D and technological innovation trends are dominated by equipment and system suppliers in opposition to the former leadership of the old monopolist service providers R&D initiatives (Fransman 2002b). This fact by itself is part of the explanation of the new R&D organisational patterns, for system suppliers now compete overtly in a global market, not being restricted to their own country's strategy.

Literature uses two criteria to propose taxonomies of internationalised R&D. One of them is based on the nature of technological activities taking place in foreign R&D units, and the other is based on the motivation of the leading multinational company. UNCTAD (2005b, p. 138-139) provides a literature review that presents many types of R&D units, according to the criteria used. The first of these leads to a taxonomy of local adapters, locally integrated labs, international technology creators and technology scanning or monitoring unit. The other suggests types of R&D units according to their activities as an answer to the technological goals of the corporation: technology-seeking, home-base exploiting and home-base augmenting. New technologies, especially ICT, have facilitated the organization of dispersed technological activities, providing a counterbalance to the classical problems related to the flow of information between subsidiaries and allowing greater separation of production- and R&D-related activities (UNCTAD, 2005b, p. 160). The growing specialisation and modularisation of R&D activities – as explained previously – allow the separation of its components in different locations, providing greater efficiency and cost reduction (UNCTAD, 2004 e 2005b, p. 160). In a worldwide market competition, this is of great help to the firms' strategies.

In summary, economical and regulatory liberalization and competitive pressures have stimulated the internationalisation of R&D activities in the telecommunications sector. These factors are supported by recent changes at the knowledge base, originated by the technological convergence of telecommunications and IT and the role of standards, enabling the division of work by means of interoperable modules, thus creating a requirement for the development of different organizational models for R&D units, according to their activities or motivation (Figure 3).

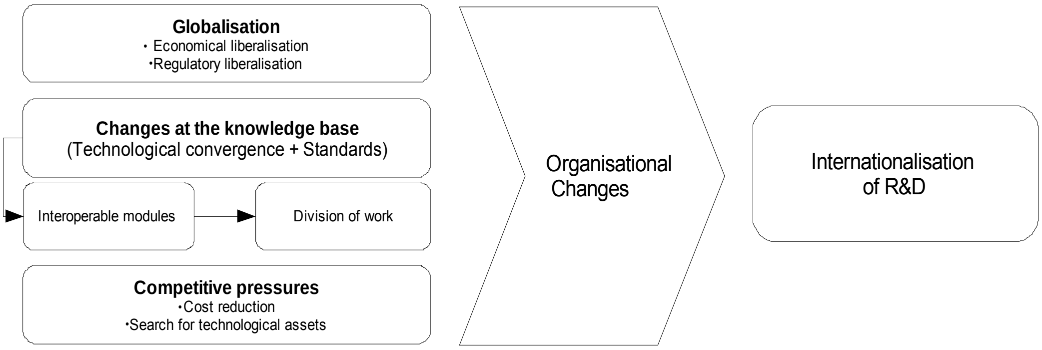

Figure 3 Elements Acting In Favour Of Internationalisation Of R&D In The Telecommunications SSI

2.2 Software in Telecommunications R&D

By analysing even further the building blocks of the telecommunications SSI, the purpose of this section is to explain how software development has become a key activity in R&D in telecommunications, by means of a historical sequence of transformations. It begins with the digitalisation of technological artefacts that comprise sectoral products and the development of embedded software. Then it explains the concept of network programmability, amplifying the role of software in telecommunications. Afterwards, it presents how the technological convergence between telecommunications and IT amplified even the role of software in this sector. From there, this section explains how the evolution of demand, marked by the development of an information society, brings many challenges to sectoral actors and to the software included in telecommunications goods and services.

2.2.1 Digitalisation and the development of embedded software

According to previous research (Furtado, Rego and Loural, 2005a and 2005b; Loural et al., 2005), the development of microelectronics and microprocessors led to the digitalisation of many artefacts that put together the telecommunications network infrastructure. Digitalisation allowed the development of specialized computer systems, which, opposed to generic-use computers such as a PC, are dedicated to specific tasks, allowing the reduction of equipment size and cost and also taking advantage of the benefits of mass production. Software embedded in these systems have to interact with the physical world, in a sense that it has to take into account certain aspects related to time, energy consumption and failure tolerance (Lee, 2002), features that need to be present in the many machines that have software loaded in them, such as cars, guns and telephones.

Generally speaking, telecommunications gear has become a specific type of computer system specialised in certain functions, such as telephony and data transmission. For example, the substitution of analogue telephony switches by programmable switches began in the 1980's, which were specialised hardware controlled by the software embedded in their microprocessors. Thus, the concept of telecommunications software was created.

2.2.2 The development of network programmability

Until the 1980's, telecommunications services were synonym to telephony, whose network infrastructure consisted of transmission and switching equipment based on specialised hardware and in the software embedded in that very hardware. Moving away from the equipment area and going up to the network level, until then software existed only for basic management and control of that infrastructure (Zuidweg, 2002).

Only with the development of signalling system number 7 (SS7), it was possible to structure a signalling network independent of the physical network, to control the interconnection of telephony channels from the equipment that comprise the telecommunications infrastructure. Such control was now performed by a network of programmable nodes, called Service Control Points (SCP), which allowed for the first time the development of intelligent call processing services, such as phone number translation and special billing functions. Thus way the idea of "network programmability" was created (Zuidweg, 2002).

In short, telecommunications software, which once performed only the role of embedded software or management and control software, began existing also as something to allow the development of new intelligent services, being able to be physically located outside the equipment on which such services were based.

2.2.3 Technological convergence

The development of network programmability was in itself a huge sectoral transformation, which allowed the growth of the role of software in telecommunications. Moving beyond that, as explained earlier, the telecommunications sector went through great transformation in the last decades, which also brought reflections to the role of software.

Until mid 1980's, the sector was dominated by big monopolist service providers, but after commercial and regulatory liberalization initiated in USA, Europe and Japan, monopolies were abolished and thus began the development of new sectoral actors (Fransman, 2002a and 2002b; Henten, A.; Falch, M.; Tadayoni, R, 2004). The understanding of these transformations and the search for a model to explain them are important to develop a concept of telecommunications software.

Fransman (2002a and 2002b) suggested a layer model to explain the new sectoral features, which are strictly related to a value chain model. In Fransman's model of the old telecommunications industry there is a base layer (layer 1), which refers to the equipment allowing the deployment of telecommunications networks (layer 2) and services (layer 3). Before the liberalization and technological convergence, the operation of telecommunications services were usually vertical or quasi-vertical, meaning that many countries had one monopolist service provider which either developed and manufactured the equipment needed for network operation and service provisioning (such as old AT&T in USA) or bought these equipment from a set of few preferred manufacturers (such as Japanese NTT) (Fransman, 2002b). The present scenario is one in which the role of developing and manufacturing those equipments have become an exclusiveness of the communications equipment manufacturers. At the same time, the other layers could be explored not only by the incumbent service providers, but also by new entrants, such as mirror companies, portals, Internet service providers and application providers. Moreover, traditional suppliers of telecommunications gear began competing with new or old suppliers coming from the IT sector (Henten, A.; Falch, M.; Tadayoni, R, 2004), such as Cisco, IBM and HP.

What interests in this layer model for this paper is the way it explains the growing role of software technologies in the telecommunications sector. Firstly, there was the separation between network (old layer 2) and service (old layer 3), facilitated by the consolidation of the use of the IP family of protocols used in the Internet and data communication networks in general. Such protocols are all basically computer programs responsible for the flow of information between the many elements that compose the telecommunications infrastructure in each layer. Secondly, there was the breaking up the service layer (old layer 3) into many others, including network connectivity (new layer 3), navigation in many service and content providers (new layer 4) and applications, which allow real interactivity and content distribution (new layer 5). All these layers, traditionally from the IT sector, are software-intensive, which demonstrates how software began performing a fundamental role in the telecommunications infrastructure.

Another model used to explain the sectoral transformations is related to the scientific structures of telecommunications and computer communication, the building blocks of digital communication (Engelstad, 2000). In this model, each of these two areas are analysed in terms of their scientific structures and paradigmatic elements. The merge between these different paradigms and the evolution towards a new "research program" for the relevant scientific community ended up bringing to the telecommunications sector features that formerly were present only in the traditional IT sector. Elements from informatics, such as decentralised control, product focus on applications, short durability of services, packet switching, flexibility requirement for the user and short development datelines, all put pressure on the telecommunications sector manufacturers to become more dependent on software development. In this short innovation lifecycle arena, equipment hardware tends to become standardised and it is in software that resides the greatest amount of value added to it. A study from TNO/IDATE (2005) showed that software-related R&D answered for 56% of all R&D in the telecommunications sector in 2002. For example, during the last 40 years, Swedish Ericsson has migrated its R&D effort from hardware to software. Nowadays, the company invests 85% of its R&D budget in software development (Goldstein and Hira, 2004). This sectoral trend can also be seen in the results of R&D activities. According to Bessen and Hunt (apud Cukier, 2005), the growth in the number of patents in this sector for the same amount of R&D capital invested is, in part, a result of the growth of software patents.

In short, the two models show that the result of technological convergence is the growing role of software in innovative activities in communications equipment manufacturers, which provide the sectoral technological artefacts necessary for the deployment of the telecommunications infrastructure.

2.2.4 The information society

In a SSI, instead of seeing demand as only an aggregate set of buyers of similar features, it is considered as "being composed of heterogeneous agents the interaction of which with producers is shaped by institutions" (Malerba, 2004). The globalisation process described earlier in terms of commercial and regulatory liberalisation has created the institutional basis for the development of a new society demanding input from three sectors formerly separated: telecommunications, IT and content. It is less and less obvious the separation between the two components that conform the larger ICT sector – telecommunications and IT – and also the separation between ICT and the content sector. Figure 2 tries to illustrate, in a very simplified way, the links and complementarities between the two ICT sectors and the content industry.

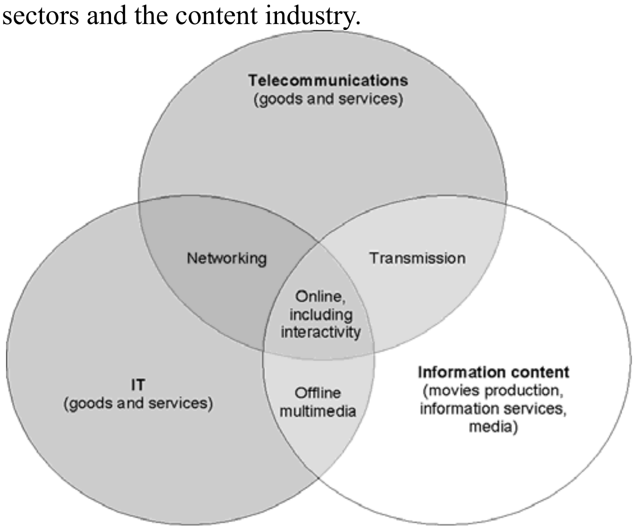

Figure 4 ICT and Content Sectors (OECD, 2005)

The three phenomena presented in this section – digitalisation, network programmability and technological convergence – along with globalisation, intensification of competition and the development of an information society, all contributed to the telecommunications SSI assuming new features, also in respect to demand. According to Zuidweg (2002), the telecommunications network has become heterogeneous, competitive and highly complex. In this new context, telecommunications services can be provided by many different technological means, such as ADSL, cable, satellite and mobile networks. Such services carry a plethora of digital content coming from an uncountable number of sources, bringing new dynamics to the demand for sectoral products. The biggest challenge for telecommunications service providers and for those that develop the infrastructure gear for them, is to find out how to provide the most diversified set of services in an heterogeneous environment, at the same time as they keep simplicity in the creation, maintenance and usage (Zuidweg, 2002). This has become also the challenge for telecommunications software.

In summary, this chapter discussed how changes at the building blocks of the telecommunications SSI – knowledge and technologies; actors and networks; and institutions – have not only driven the internationalisation of innovation activities, but also made software development one of the most important set of R&D activities driving the evolution of this SSI.

This opens opportunities for labs around the world to become more involved in global innovation networks, especially in activities related to software development. The software industry as a whole is know for being associated with very high technological opportunities and for having a great amount of innovators that are geographically concentrated both in local and global boundaries (Breschi and Malerba, 1997). Software-related innovative activities are also one of the drivers of technological alliances in the telecommunications SSI (Rao, 1999).

3 The National Dimension: the Brazilian Case

The previous discussion concerned only sectoral features and cannot be the only elements used to explain why labs across different nations differ in terms of scope of activities and capital invested in them and also in terms of their ability to enjoy such opportunities in global innovation networks, such as those related to software development. Malerba (2004) alerted for a relationship between the SSI as a whole and the national system of a given nation. In other words, the features of a nation have an impact not only the effect internationalisation drivers have on it – and consequentially its international performance – but also the way different sets of innovative activities span different nations.

In order to understand what determines a nation’s position in the internationalisation of R&D, this papers draws from well-established literature that concerns attraction factors related to technological activities. This literature helps understand why specific locations are chosen in despite of others when it comes to select how an innovation network should spread its branches throughout the world. It is not the intention here to present a bibliographical review on this matter, but only to bring to this discussion the main points that can be considered both a somewhat consensual view and helpful for this sectoral analysis. More detail can be found on works from Chiesa (1995 and 2001), Ares (2002), Zedtwitz and Gassmann (2002), UNCTAD (2004) and Thursby and Thursby (2006). According to work from Chiesa and Zedtwidtz and Gassman, R&D activities are attracted by two categories of factors: factors strictly associated to the nature and content of R&D activity and non-R&D related factors. This taxonomy helps the analysis of a country’s attractiveness not only by means of elements intrinsic to R&D, but also by those related to the environment in which firms in that country have to operate.

Table 6 Factors Attracting R&D Activities

R&D related factors	Supply of qualified labour Cost of qualified labour Supply of science and technology institutes for R&D partnerships Market size and growth potential Proximity to market
Non-R&D related factors	Current existence of business operations Instruments for the protection of intellectual property Basic infrastructure Instruments for funding and financing of R&D activities Social-political-economical environment

Source: Leal (2007)

Since the goal of this paper is to discuss implications to human resources management due to transformations in the telecommunications SSI, the focus here is only in three of the attraction factor listed above: supply and cost of qualified labour and supply of science and technology institutes for R&D partnerships. According to previous research (Leal, 2007), technological assets such as these three are also the most important factors determining the attractiveness of a country in terms of R&D activities. This chapter will draw heavily from the findings of that research, providing only the main findings discussed there, and also from other references, where indicated.

3.1 A note on Brazil's telecommunications context

The development of Brazilian telecommunications industry has been described in (Loural et al. 2006). Until the '80s, a protectionist economic policy was executed mainly by means of the procurement practices of TELEBRAS, the state-owned telecommunications monopoly. However, high inflation and political changes in the beginning of the '90s were unable to sustain the existing import substitution approach and the model of indigenous technological development broke up. What remained was an already existing installed basis of multinational manufacturers and a few small local companies occupying a few product niches. The end of TELEBRAS monopoly and concomitant privatisation in 1998 exacerbated this picture. Foreign operators bought parts of the former state-owned company and brought into Brazil several multinationals with which they had links and agreements abroad, turning Brazilian telecommunications market much more interwoven with the global market.

Other causes may have contributed to the dominance of foreign suppliers over local firms, some of which are relevant to understand the present situation, detailed below. There was an insufficient exploration of the synergies propitiated by digitalisation and convergence processes. Probably, there were also not enough input capital and qualified manpower to let the national innovation system to follow the technology trajectory, which was being carried out abroad by the telecommunications sector.

Notwithstanding, the emergence of software as a key driver of technical evolution of the sector has opened new possibilities for Brazil to play a significant role in telecommunications market. The following analysis will focus in some of the factors, and some suggestions for better profiting of such an opportunity will be made in section 4.

3.2 Supply of qualified labour

As an *input* to the telecommunications SSI, qualified labour can be analysed in terms of its availability for training and employment in new R&D projects developed in Brazilian labs.

Even though it has one of the largest populations in the world – almost 200 million – Brazil can be placed in an intermediate position in terms of this SSI input, with China and India standing out from the rest of the world. This "second tier" position is due to some few limitation factors.

The first one can be considered generic and refers to the low population access to university education and the small share of science and engineering (S&E) courses. The UNESCO Database of Statistics shows that in 2004, Brazil had around 18 million people with school age, but only 4 million enrolled in undergraduate courses, compared to 19 million in China and 11 million in India. From a sample of 15 competing countries, Brazil was in good position in the absolute number of students enrolled in S&E courses, but when in comes to the proportion of these courses in the overall courses, it dropped to last place, with only 16%, while Mexico, Philippines and Malaysia were around 30% and South Korea had 40%.

The second factor, now specific to this SSI, comes forth when only those courses directly related to its knowledge base are taken into account. These courses are losing their appeal in past years, since the growth ratio of new graduates coming from courses such as electrical engineering and computer science (7% between 1999 and 2003) is lower than the growth ratio from overall courses (13% in the same period). This means "infocommunications" seem to be losing relative importance in the career choice of future professionals. Such evidence is even more preoccupying when it is considered the fact that the telecommunications SSI competes for available labour with traditional IT players and these are already pointing out gaps in the supply of qualified labour (Cristoni, 2006; Computerworld, 2007; Fuoco, 2007).

The third factor, also specific to this SSI, refers to the qualification of new professionals coming out of universities. In terms of their localisation, the majority of new "infocommunications" professionals (80% between 1999 and 2003) comes from south and southeast regions of Brazil, which are the ones hosting most telecommunications firms. This means that qualified labour lives within close reach, something very important in a country with such large geographical dimensions as Brazil. In terms of distribution of courses throughout the relevant knowledge base, courses that traditionally had a straighter link to IT are responsible for over 90% of "infocommunications" undergraduates. As explained earlier, technological convergence implies the aggregation to telecommunications of even more IT-related scientific and technological disciplines. This means that Brazil seems to be somewhat aligned to the evolution of the telecommunications SSI knowledge base. Besides these two positive features, Brazilian firms perception on the quality of available professional is not something to considered positive, something already pointed out in (Fusco, 2007) and verified in all Brazilian

Technological Innovation Surveys. In 2005, a national exam on students from courses deeply related to telecommunications showed that over 93% of these courses were below the acceptable average. English language proficiency is also a disadvantage towards Brazilian supply of qualified labour (Cristoni, 2006; Cherobino, 2007), something that places India in a great spot, since it has the second largest English speaking population in the world (Moreira, 2006).

3.3 Cost of qualified labour

Using data from the Brazilian Annual Industrial Research database, when measured in Brazilian reais, the mean monthly salary of the telecommunications sector in Brazil has been growing systematically, jumping from R$ 2,807 in 1999 to R$ 5,268 in 2004. But even though the Real (R$) has suffered strong devaluation in that same period, when measured in US dollars, the same positive trend appears, which suggests an inflationary force acting on the cost of qualified labour. In 1999 the mean salary was US$ 1,310 and in 2004 it rose to US$ 1,827, a trend that may be worsened by current worldwide devaluation of the US dollar. Another issue that must be considered is the fact that there is at least a 34% increase on the base salary of this sector, due to imposed labour and social charges and benefits paid to these professionals, something that is usually negatively cited in press articles by companies executives.

These numbers alone do not mean much in terms of positioning Brazil in a good or bad position, unless other direct competing countries are considered. For such comparison, the cost of this input must be analysed by considering the sectoral evolution in terms of basic technologies that have to be mastered by researchers in order for this input to be considered attractive or not. In that sense, the previous chapter showed that software-related technologies are becoming an important piece in the set of capabilities required for R&D professionals in this SSI. Thus, professionals specialised in software are here considered as the basis for labour cost comparison between Brazil and other nations.

A research (BRASSCOM, 2005) showed that while a Brazilian software developer earns US$ 13.5 thousand per year, in Canada and Singapore this number rises to US$ 36.4 and US$ 33.5 thousand, respectively, something that places Brazil in a fair position for competing in terms of costs with these countries. On the other extreme, in India, Philippines and China, programmers earn less than Brazilians. Indians are considered the least expensive ones, earning US$ 5.9 thousand per year. These countries may have advantages over Brazil, but the differential cost between these countries and Brazil is less than the differential cost between Brazil and Canada or Singapore.

When additional managerial capabilities are taken into account, the position of Brazilian professionals can be considered superior to the Chinese. That research pointed that a Brazilian manager has an annual salary of US$ 32.5 thousand, while a Chinese earns US$ 36.2, which implies that Brazil can be competitive when additional managerial capabilities are included in the labour cost analysis.

3.4 Supply of S&T institutes (STI) for R&D partnerships

Also an *input* to the telecommunications SSI, the supply of STI as potential R&D partners, must be analysed by means of its dynamic links and complementarities with the type and structure of firm interaction. In such sense, this input touches another building block of this SSI, more specifically the *interaction between firms and other organisations* for the development of R&D activities. Moreover, it touches also the *knowledge base* through science and technology fields specific to this SSI.

According to Blomqvist and Kyläheiko (2000), technological convergence created new potential business areas, in which knowledge from many agents have become vital for the development of innovative activities. In their opinion, the large multinational firm in telecommunications is motivated by the possibility of gaining dynamic capabilities by means of connections to external partners in a network structure. The Brazilian Technological Survey showed that companies and institutes external to the firm are considered the main responsible for product development in 22% of innovative firms in the Brazilian telecommunications sector between 2000 and 2003, by means of direct contracts or cooperation agreements, a number much larger than the overall Brazilian industry (8%). Leal (2006) provides a theoretical discussion around the potential benefits of technological cooperation between multinational companies and Brazilian firms and institutes in the telecommunications SSI. Perini (2006) presents empirical evidence of these links by means of a study of Brazilian networks dedicated to technological activities in ICT, which places software development as the densest network in Brazil.

Two research projects conducted internally by our institute indicated that Brazil has a reasonable set of capabilities in terms of supply of research groups that are relevant for potential use as R&D resources for indigenous and multinational firms as well. It shows concentration of inputs in those science and technology fields more closely related to the knowledge base of this SSI, as well as in the regions of country that gather most of those firms. The set of capabilities in Brazil includes many technological fields applicable to hardware and software development and tests, such as wireless communications and optical-electronics. Moreover, there is a solid core of academic research groups that were formerly created under the sponsorship of TELEBRAS and have been around for decades; and there is also an indication that these capabilities are sustainable due to a positive trend of the number of new groups that have been created in the last ten years.

Although the capabilities might exist, empirical evidence indicates that technological partnerships in the Brazilian telecommunications SSI are, in its majority, dedicated to complementary activities necessary for product development (the “D” in R&D), with great emphasis on technological fields deeply related to software knowledge. Such evidence also shows only few partnerships dedicated to applied research in fields such as wireless and optical communications, but no indication of basic research. These findings corroborate other researches on technological partnerships in telecommunications in Brazil, which show that these are sporadic and with limited scope (Porto, Prado and Plonski, 2003; Galina, 2003).

These findings suggest that, even though the capabilities are potentially present in the supply of STI, there might be some factors limiting the amount and scope of technological partnerships between firms. In the first place, the amount and scope of technological partnerships in Brazil are limited by the role of the subsidiaries of multinational companies. Multinational companies are the largest investors in R&D activities in Brazilian telecommunications SSI, while only few mid-sized national technology firms still exist, focused in parts and components with low technological specialization or concentrated in niche markets (Oliva apud Szapiro and Cassiolato, 2003). That means that the strategic motivation of Brazilian subsidiaries, in great part related to software development and adaptation of products to local requirements, have a direct influence in the way local ICT are brought to the innovation network around the former. In other words, the scope of partnerships with subsidiaries is only an extension of the global mandates given to their local R&D labs, which are limited.

In second place, another limiting factor comes forth when the firm-university interaction is seen as a key peace of the system of innovation, more specifically a subsystem of knowledge exchange (Rapini e Righi, 2006). In that sense, the contribution of universities to knowledge growth becomes larger when they are capable of assisting the need for change in a sectoral system and when firms develop the capabilities needed to absorb the knowledge generated by universities (Rosenberg and Nelson, 1994)). Thus, inefficiencies in university-firm relationship can be seen as the result of existing gaps in the Brazilian system of innovation itself. The typical institutional arrangement in advanced industrialised countries such as USA, Germany and Japan, is developed in such way that it creates strong “relevance signals that lead to the formation of virtuous relationships between research and production, innovation inside firms and competitiveness of a nation” (Dagnino, 2004). The inefficiencies and fragilities in the Brazilian past of university-firm relationship originated from many problems, such as low scientific content and short time frames required by industrial solutions that do not stimulate firms to invest in science and technology, absence of capable interlocutors in Brazilian firms making it difficult for them to communicate their needs, low innovativeness of the Brazilian productive system, absence of instruments fit to the commercialisation of technology in Brazilian universities and inflexibility of Brazilian STI (Rapini, 2004).

4 Implications for Human Resources Management

The discussion presented in Chapter 0 showed that the telecommunications SSI has been going through transformations in its building blocks, which provide a window of opportunity for indigenous firms and research institutes and subsidiaries of multinational companies throughout the world to become part of a global innovation network. It also suggested that software development might a promising activity in this internationalisation process. Although this window seems to be open, features that are specific to a nation’s system of innovation may not only boost its competitiveness in terms of being a target for future global investments in R&D activities, but also narrow the set of possibilities in terms of scope and investment in R&D, as shown in Chapter 0.

Brazil has proven capabilities in software development, not only in telecommunications but also in traditional IT-related systems, such as information systems. Nevertheless, it also has many limiting factors to R&D investment attraction. In other words, there is an interplay between sectoral sytems and national systems that somehow drives the distribution of innovation activities throughout the world and defines the role of firms in a given country.

This chapter intends to focus on the limiting factors originated in the Brazilian national system (Table 2) that interact with those three inputs of the telecommunications SSI that are an important source of competitiveness of R&D investment: supply and cost of qualified labour and supply of local institutes for potential use in technological partnerships.

Table 7 Brazilian Limiting factors To R&D Activities In The Telecommunications SSI

Inputs of telecommunications SSI attracting R&D activities	**Limiting factors from Brazilian national system**
Supply of qualified labour	Low population access to undergraduate courses in general. Small share of S&E courses in overall undergraduate enrolment. Low supply of S&E courses closely related to telecommunications. Perception of low quality of professionals formed by telecommunications-related courses. Relative low relevance of telecommunications in the career choice of students. Competition for labour with traditional IT-related sector, which already have shortness in labour supply.
Cost of qualified labour	Inflationary salary trend. High cost of social charges.
Supply of S&T institutes for R&D partnerships	Limited scope and investment in R&D by subsidiaries of multinational companies. Difficulties in university-firm interaction.

Before doing that, it is important to highlight one important consideration. The three SSI inputs considered in this paper are not the only ones that affect the attractiveness of a nation as a potential location for investment in innovative activities. As shown in table 1, there are many other R&D- and non-R&D-related features of a national system that interact with a sectoral system, such as the market size and growth potential of a nation or region, its instruments for the protection of intellectual property and also its social-political-economical environment. Nevertheless, those three inputs focused in this paper are considered here as the most intimately related to human resources management – the focus of this paper – and thus provide the most straightforward implications to it.

4.1A more proactive approach for strengthening local links

The first implication for human resource management is related to the attitude of innovation managers in Brazilian firms. Unless they realise they have to be the drivers of investment attraction and act proactively in attacking the gaps in the Brazilian national system of innovation, the picture probably will not change for better. One can argue that the three inputs highlighted in table 2 and all of those attraction factors presented in table 1 are more or less affected by public policies and thus firms should focus their efforts on influencing policy makers to provide some relief of the limiting factors acting against the nation's attractiveness. But the authors' opinion is that public policies alone are not enough and their effect on the limiting factors can only be detected in a long time span. Thus, if R&D management personnel in local firms – national or multinational – do not take action themselves, they may lose a window of opportunity in becoming part of global innovation networks. Many of the limiting factors influencing the three SSI inputs are within reach of local R&D managers by means of actions created specifically for them.

Firstly, many of the limiting factors acting against the supply of qualified labour can be softened by means of interactions with second-degree schools and universities. Second-degree schools, such as technical schools, can be approached with the goal of influencing students in their future choice of which university degree to pursue. This should not only include career-advising activities, but also the creation of labs that could become a nest of potential technological partnerships. This should also be one of the goals of partnerships with universities. These partnerships should also be encouraged by actions related to the design of specific graduate and undergraduate courses related to the knowledge base of activities pursued by the firm. In a sector characterized by short technological life cycles, it is important that universities follow the change in knowledge base and relevant technologies that are needed for R&D activities demanded by firms.

Secondly, the cost of qualified labour can also be object of some actions developed by local managers. All the actions suggest in the paragraph above may have a negative impact on the cost of innovation activities, but if firms associate with each other in partnerships and associations, this could reduce the cost pressure. Microsoft has been doing this with its Brazilian channel partners, placing the nation as number one in the world in online training (Americano, 2007). Also, firms should invest not only in in-house training but also in partnerships with local educational institutions, in order to broaden the set of capabilities dominated by local human resources. Technical knowledge is very important and should be pursued through those actions, but other managerial capabilities and foreign language proficiency could help shift the focus of attractiveness of local human resources away from cost-related features towards qualification-related ones. This could even reduce the overall cost of local R&D activities, since a pool of more qualified human resources may need less time do to the same work with less rework.

Finally, the two set of actions suggested above act in favour of the third SSI input: local S&T institutes. The fragile interaction between universities and firms should be strengthened by the technological partnerships and other interactions discussed above. Moreover, it is expected that if local subsidiaries become able to attract more investment to their local R&D activities, indigenous firms and S&T institutes could benefit from this if they were able to offer the complementary assets needed for the activities taking place locally.

4.2 A more proactive approach towards software development

A second implication derives from change in knowledge base and relevant technologies in the telecommunications SSI. The fact that software development has become a major element in innovative activities in this SSI is positive for firms located in Brazil. Software-related activities are human resources intensive, which makes possible the investment in innovative activities that not only renounce the need to spend on costly hardware development processes and equipment, but also can overcome, at least in part, the gaps pointed in table 2.

Local innovation managers in indigenous firms and S&T institutes and local subsidiaries of multinational companies should pursue the identification of complementarities, synergies and new opportunities for their local R&D labs, considering as a prime requisite the fact that they should be part of a global innovation network. These actions may include technology-monitoring activities and the development of portfolio management frameworks, which could help identify in which technological areas the local lab has capabilities and in which areas it should develop new ones.

Previous research (Leal, 2008) has identified a taxonomy for software in telecommunications based on its application or use: software in telecommunications equipment; software in services platforms; software in operations support systems; and software in business support systems. The first two are related to the software that can be considered essential to the remote communication process (Oliveira, 2004) between two points. The last two are designed to provide support to the infrastructure required for telecommunications services (Oliveira, 2004; Triple Tree, 2001). This taxonomy is helpful for identifying which type of software-related technologies should be pursued by innovative activities since it is easy to point out where the final products of a given firm are located in the taxonomy. The identification of those technologies thus becomes critical for human resources management, since R&D staff should have capabilities in them in order to become attractive for development projects of any given product.

The identification of technological trends in telecommunications software is a process inherently difficult, since it still deals with two different research traditions – computers (or IT) and telecommunications – despite the convergence explained earlier in this paper. This means the literature on technological trends usually does not focus the conjunction of these two sectors with specific regards to software. The bibliographical review presented by Leal (2008) showed that there are few attempts to study software-intensive technologies in telecommunications in a broad and systematic approach, and when there are any, they are either outdated or with too restrictive scope. To overcome this problem, one of the approaches suggested by Leal is based on computer science disciplines intimately related to telecommunications knowledge base. The advantage of this approach is the fact that it provides a framework for the identification of the science and technology fields that are more important for the development of human resources, which could be done in partnership with local universities and training programs.

In order to test this approach and identify potentially relevant software disciplines for telecommunications, a research was carried out within our institute with the help of expert members of its technical staff. One of the findings from that research was that some telecommunications software-related technologies might be considered *pervasive*. This means some science and technology fields are related simultaneously to many telecommunications software-related technologies, since they were identified as being highly relevant to more than one of the four categories in the taxonomy referred earlier, and eventually all of them (software in telecommunications equipment; software in services platforms; software in operations support systems; and software in business support systems).

That research also suggested that some technologies might be more relevant for the future evolution of the sector, in other words, they are *future-outlooking*. Taking into account different time frames allowed the identification of which technologies, although not considered relevant today, might be highly relevant in the near future. This may answer questions related to the identification of future trends in the knowledge base of the telecommunications sector.

Finally, that research proposed three groups of telecommunications software-related technologies. In the first group are those technologies identified as highly relevant today in more than one category of telecommunications software and as promising for the future in a different category. This means that certain technologies that are widely used in many products in the present may be relevant for other products in the future, leveraging its pervasiveness even more. The second group includes technologies that, although not important today, will be highly relevant in the future in more than one category of products. These are the futurist pervasive technologies, employed in a wide range of products. The third group refers to the technologies that are also not important today in any category, but will be highly relevant in the future in only one category, in other words, they will be relevant in niche products. These three groups can be pictured in terms of two dimensions – timeframe and pervasiveness (

Figure 5). The first dimension refers to the time horizon a certain technology is considered to be relevant in technology-monitoring activities: present or future. The second is how pervasive certain technologies are considered in technology-monitoring activities, or in other words, how universal or restricted they are in terms of the number of software categories that may require them.

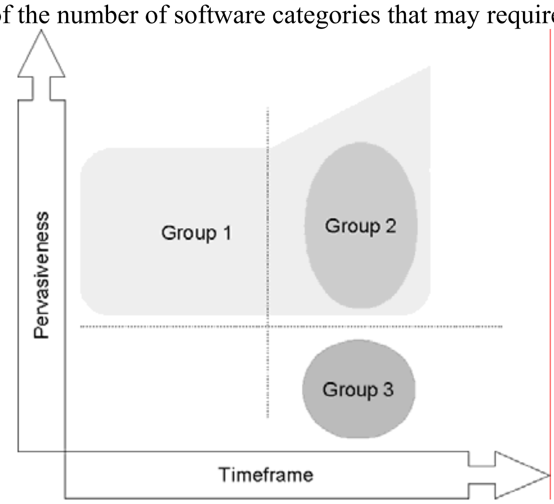

Figure 5 Groups of Telecommunications Software-related Technologies

The framework presented here can be useful in two ways, both with direct impact on human resource management: one for capability building and another for portfolio management.

Firstly, depending on the strategic orientation glimpsed by management staff, in terms of in which parts of the global product development they wish their R&D lab to be, the framework helps focus its efforts, since one or another set of technologies identified gain importance and thus should be the focus for capability development of their human resources and external partners. For example, if the technological mandate of company is to deal with one of the four categories of telecommunications software, such as services platforms, its human resources management should be directed towards those technologies identified in technology monitoring activities as highly relevant for that category. If the firm intends to expand its scope in the future with a product from another software category, it should chose a product from the company portfolio that may depend in the future on the same family of technologies that are currently dominated by its human resources. Those capabilities that cannot be developed in-house might be pursued externally by means of technological partnerships with local firms and S&T institutions.

Secondly, the identification of those three technological groups **(**Figure **3)** is very helpful for portfolio management suggested in the beginning of this section. Technology-monitoring activities such as the one presented above can be used as one of the inputs for the definition of which technological strategy that the local R&D management should pursue. The strategy would be a combination of product development projects that span the four software categories and each of the three technological groups identified here. For example, an indigenous S&T institute may be part of a development project in partnership with a multinational company dedicated to a product category that presently depends on a set of technologies from Group 1, foreseeing it could expand its participation in the future towards other product categories that depend on the same set of technologies. At the same time, this institute may have other projects from other product categories and technological groups. The combination of these projects comprises the strategy used for portfolio management and defines what kind of human resources the firm needs today and in the future. It also helps reduce risks associated to the choice of one or another technological path which to follow.

5 Conclusion

This paper has shown that recent wide transformations in the telecommunications sector could explain how software-related activities became important for its R&D and innovation patterns. Globalisation and competition, along with the digitalisation of sectoral artefacts and the creation of network programmability concept, have also changed sectoral demand patterns around a new information society, which created challenges for all innovative activities undertaken by sectoral players. Systems of innovation around software players are usually associated with high technological opportunities and a vast numbers of these players across the world, driving also technological partnerships.

We discussed how the features of a nation such as Brazil influence its competitiveness in terms of the attraction of R&D activities to its geographical boundaries and thus its position in global innovations networks. The focus of discussion were the three attraction factors which are also inputs for the telecommunications SSI: supply and cost of qualified labour and supply of S&T institutes for R&D partnerships. The interplay between a sectoral and a national innovation system showed that some positive trends could be identified: good position in the absolute number of students enrolled in S&E courses and its alignment to the evolution of the telecommunications SSI knowledge base; geographical proximity of universities to firms; intermediate relative position in terms of salaries, which gets better when additional managerial capabilities are taken into consideration; solid and sustaining core of research groups; and existence of technological clusters, specially in software-related activities. Despite those positive trends, there is still a list of elements limiting Brazilian competitiveness, such as relative low relevance of telecommunications in the career choice of students; perception that the amount of qualified professionals is not enough; low proficiency in foreign language; rising salaries; and difficulties in university-firm relations.

The implications for human resource management as a consequence of the interplay between telecommunications (sectoral) and national innovation systems were then appraised. Instead of waiting for public policies to deal with the limiting factors, the authors suggested a proactive approach by local innovation managers towards strengthening local links in order not to lose a window of opportunity to become part of global innovation networks. Many limiting factors can be dealt with by actions direct to strengthening the ties with second-degree schools and universities. Also, firms should associate in consortia-like structures to reduce the cost of some of those actions proposed and also invest in building capabilities that are complementary to technical ones, such as managerial capabilities and foreign language proficiency.

The authors also suggest proactive approaches also with respect to software development activities, which are human resource intensive and thus do not require large investments such as those needed for hardware development. Local players – indigenous firms and S&T institutes and subsidiaries of multinational companies – should pursue capability building actions – such as training and partnerships – by means of a combination of technology-monitoring and portfolio management frameworks, which could help identify in which technological areas the local lab has capable human resources and in which they should be pursued.

Finally, this paper presented a plausible approach for building a framework for the identification of the science and technology fields that are more important for the development of human resources. Firstly, it introduced a taxonomy for telecommunications software-related products, which helps the innovation manager to identify the possible uses of software in sectoral products and services and where the present and future development activities of his lab are located in the taxonomy. Secondly, it suggested a method for the identification of science and technology fields that are relevant in each of the four software categories. These fields can be grouped according to how their relevance for innovation activities are foreseen in terms of two dimensions: pervasiveness in sectoral products and services and timeframe for reaching high relevancy in sector products and services. The strength of this approach is the fact that it can be used in two ways and both of them have to do with human resource management: capability building and portfolio management.

Is it important to highlight the fact the many elements limiting the attractiveness of Brazilian labs can, or hardly can, be touched by the actions pursued by the local innovation managers. The low proportion of the population with university access is one of them. Also, as pointed out earlier, the three factors analysed here (supply and cost of qualified labour and supply of S&T institutes for R&D partnerships) are only a small set from the overall elements that have direct impact on a nation's competitiveness in terms of R&D attraction. There are those such as market size and growth that are hardly included in the set of possibilities for a single manager. However, proactive approaches, as the ones suggested in this paper, undoubtfully can influence the competitive landscape for R&D activities and place a national system, like the Brazilian one, in a better position at the telecommunications sectoral system of innovation.

Acknowledgement

This work was partially supported by FUNTTEL – *Fundo para o Desenvolvimento Tecnológico das Telecomunicações*, Brazilian Ministry of Communications, under grant to the project "*Cenários Tecnológicos de Telecomunicações*".

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