ORGANISING INNOVATION BETWEEN MULTINATIONAL COMPANIES AND INNOVATION SYSTEMS:

THE BRAZILIAN ICT SECTOR IN THE LATE 1990S AND EARLY 2000S

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LIST OF ABREVIATIONS

BRIC	Brazil, Russia, India and China
CITS	International Centre of Software Technology
CMM	Capability Maturity Model
FDI	Foreign direct investment
FINEP	Funding of Studies and Projects
ICT	Information and Communications Technology
INATEL	National Institute of Telecommunications
IPT	Institute of Technological Research
MCT	Ministry of Science and Technology
MNC	Multinational Company
R&D	Research and Development
SEPIN	Secretary of Informatics Policy
SIS	Sectoral Innovation System

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ABSTRACT

This thesis is concerned with the organisation of innovation in the interaction between multinational companies and host-country innovation systems. It proposes a framework for characterising the decentralised governance of innovation projects in sectors and identifying emerging organisational configurations in this specific context. The general characteristics of the project-based knowledge networks are examined in terms of (i) the shifting boundaries between subsidiaries and technological partners, (ii) the specialisation of actors in types of activities and (iii) the speed of change in the collaborations between multinational companies and technological institutes. The emerging configurations are classified in terms of (i) the knowledge and resources flows in different innovation projects and (ii) the common aims of the different groups of stakeholders. This framework is applied on the decentralised networks of innovation projects in the Brazilian ICT sector promoted by tax incentives to innovation activities ("Brazilian ICT Law"). The empirical analysis combines the data of more than 10,000 innovation projects and in-depth case studies on the organisation of innovative activities in 11 R&D laboratories in subsidiaries of multinational companies and 11 of their main technological partners. The analysis of the project-based knowledge networks and emerging configurations is recognised as a useful tool for examining the dynamics promoted by the sectoral policy. This research provides insights on how the institutional framework such as the Brazilian ICT Law provided the space for the decentralised interaction between different organisations with very different interests. The analysis also shows that the regulation may support higher investments in R&D, but it does not necessarily enforce a project portfolio that promotes a sustainable knowledge flow between multinational companies and the sectoral innovation system. Finally, the thesis includes specific recommendations for addressing key challenges such as the organisational development of the subsidiaries, the emergence of private research institutes and the coordination of sectoral policies.

Keywords: sectoral innovation systems, knowledge network, organisation of innovation, economic sociology, R&D policy, innovation projects, project-based learning, interorganisational networks.

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1. INTRODUCTION

Knowledge must come through action; you can have no test which is not fanciful, save by trial. Sophocles (496 BC - 406 BC),

What are the key organisational characteristics of the knowledge networks formed between multinational companies and innovation systems in developing countries? How could different subsidiaries sustain innovation projects among global, national and local demands? Which kind of institutions would promote a sustainable development of these the knowledge networks over time? This thesis focuses on these questions. This thesis is concerned with the organisation of innovation in the interaction between multinational companies and host-country innovation systems. In particular, the aim of this thesis is to explore how innovation projects in subsidiaries are related to the alignment between the knowledge networks formed between multinational companies and host country innovation systems, how would different stakeholders benefit from different configurations, and what are the implications for the knowledge flow between international and national networks.

1.1. POSITIONING THE WORK IN THE LITERATURE

The organisation of innovation between multinational companies and innovation systems in developing countries remains a contentious topic. The increasing integration of global economies and new forms of organising the creation and diffusion of knowledge result in a need for constructing new approaches to frame and align foreign and national networks (Dunning 1998; Gereffi, Humphrey & Sturgeon 2005; Kokko 1994; Krugman 1979; Vernon 1966).

Despite decades of research on the interaction between foreign firms and host economies, more and more, new frameworks for analysing the micro and meso-level dynamic of interaction are needed as a way to inform policy and practice in specific sectors (Katz 2003; Kim & Tunzelmann 1998; Narula & Zanfei 2003; von Tunzelmann 2004). This need is made clear by the limitations of the aggregated studies to provide a final answer to the relationship between foreign direct investment (FDI) and productivity in developing countries. Particularly in developing countries, the literature has shown that the underlying knowledge networks are not necessarily present in sectors (Duysters & Hagedoorn 2000), and even when they are, vested interests may contribute to the fact that the local knowledge networks do not pursue widely shared developmental aims (von Tunzelmann 2004).

Alignment between very different organisational aims has been considered fundamental when considering the knowledge flows between multinational companies and host sectoral innovation systems. However, alternative frameworks to the micro-level analysis of the knowledge-related interactions between multinational companies and host economies are still in short supply.

This thesis argues that analysis of networks formed by innovation projects can provide a longitudinal and in-depth examination of the activities performed by different global, national and local actors. Innovation projects are considered here as central to the organisation of innovation in most of the companies, particularly in high-tech sectors. Companies use innovation projects to explore their knowledge-base, develop new skills and appropriate from external sources of knowledge. Innovation projects provide an important way to connect the organisation of innovation in multinational firms and the disperse network of knowledge-related flows in sectors.

Although networks formed around innovation projects (hereafter, knowledge networks) are not the only mechanism of knowledge flows and spillover[1], they are increasingly important, given the dual nature between stable sectoral structures and the dynamic exploitation of complementary opportunities. In a world where most of the relevant sources of competitive advantage of a company are tacit almost by definition, understanding the decentralised organisation of the innovation in sectoral networks becomes essential for the research on innovation in firms, as well as in countries.

Naturally, the list of difficulties involved in gathering reliable and relevant relational data in innovation projects is extensive. When related to secondary data, a significant part of the learning and interaction inside companies and with different organisational are regulated by private contracts. The lack of data publicly available is particularly true in countries with underdeveloped local financial market and corporate governance practices. In this context, a large proportion of the companies do not search for local external

[1] Other evolutionary mechanisms to transfer tacit knowledge are labour mobility and firm spin-offs.

sources of finance, and, therefore, disclosure of relevant publicly available information remains limited.

Nevertheless, the use of information systems created inside the scope of specific regulatory frameworks promoting innovation projects in sectors may enable the increasing systematisation of the data about projects, actors and interactions in sectors. Giving the increasing blur of organisational boundaries and increasing decentralisation and interdependency of innovation in sectoral networks, it is important to develop new methods of analysis connecting project-level process with the evolution of sectoral innovation systems and the increasingly internationalisation of innovation. A project-level framework for analysing linkages between multinational companies and host sectoral systems may help clarify the governance structure emerging in sectors and the factors that may contribute to the sustainability of key knowledge flows.

This thesis draws upon different streams of literature to explore systemic interactions between innovation project and knowledge networks in the interaction among multinational companies and sectoral innovation systems in developing countries. Three streams are particularly relevant to positioning this research in the literature.

First of all, this thesis explores the role of innovation projects as a core mechanism for organising knowledge-related interactions in sectors. The analysis of projects moves us away from firm-centric formulations of strategic and organisational activity, bringing us closer to the process of creation of knowledge at the individual level (Nonaka & Takeuchi 1995) and the consequent diffusion of knowledge in organisational and inter-organisational communities of practice (Wenger 1999). The recent literature has highlighted that project-based knowledge networks are a useful framework to break into organisational boundaries of organisations and explore the nature of the tacit knowledge flows occurring in sectors and extract lessons for promoting their sustainable governance of innovation. (DeFillippi & Arthur 1998; Lundin & Soderholm 1995). Innovation projects are a core mechanism for knowledge creation and learning within and across firms (De Maio, Verganti & Corso 1994; Grabher 2004a; Hellgren & Stjernberg 1995; Windeler & Sydow 2001). By examining the structure of the networks based on project level data, this thesis contributes to the emerging empirical literature examining and comparing the whole interorganisational networks (Sydow & Staber 2002; Provan, Fish & Sydow 2007).

Secondly, there is a particular focus on the management of knowledge in multinational companies, focusing particularly on the management of subsidiaries of multinational companies. The increasing evolutionary growth of MNCs results in R&D laboratories with increased involvement in product development, strong interdependent and enlarged relevance of host country technology competencies (Cantwell & Piscitello 2002; Cantwell & Santangelo 2002; Hakånson 1992; Patel & Vega 1999; Unctad 2005; Zander 2002). However, the international development of these innovation activities is hindered by economies of scale in the innovation process, communication and co-ordination problems and concerns of knowledge leakage (Ernst & Kim 2002; Lall 1997). Particularly in developing countries, many important questions remain on how subsidiaries may realistically sustain their developmental path inside the increasingly complex R&D networks in multinational companies. The use of innovation projects provides a way to break into the boundaries of firm and discuss a series of interrelated issues in the international management literature such as (i) the flows of knowledge in the large multinational network (Gupta & Govindarajan 1991; Zanfei 2000), (ii) the subsidiary organisational development (Birkinshaw & Hood 1998b; White & Poynter 1984) and (iii) the possible interactions with the host economy through the development of organisational linkages (Sölvell & Zander 1998). The challenges and opportunities for the development of innovation in subsidiaries in developing countries remains a key question for understanding the evolutionary growth of subsidiaries and the multinational companies.

Finally, the thesis draws upon the emerging literature on sectoral innovation systems in developing countries (Malerba 2002). The analysis of innovation systems has become widely recognised as an approach to discussing the role of different institutions and sectoral policies in different levels of aggregation (Freeman 1987; Lundvall 1995; Malerba 2002; Mytelka 2000; Nelson & Rosenberg 1993). The need to look at systemic interactions became widely acknowledged as fundamental for identifying the evolution of firms' technological positions (Barnett & Burgelman 1996; Bell & Albu 1999; Saxenian 1991). Understanding these underlying networks in different sectoral settings can provide fundamental input for policy-makers interested in designing public-private partnerships that promote the dynamic of sectors. The analysis of the underlying networks are particularly important in early stages of the network formation, when key players and their mechanisms of interaction are still are still indeterminate, and interventions may result in a profound impact on the resulting organisation. In developing countries, micro-level longitudinal studies are particularly relevant to this literature that increasingly focuses on understanding the creation and transformation of these sectoral innovation systems.

Naturally, these three streams of literature are not independent. There are many possible interdependencies between the literature that discusses the nature of the organisation of project-based knowledge networks, the evolution of multinational companies, and the characteristics of the sectoral system. The empirical study presented here intends to contribute in different ways to these streams of literature, pointing to some limitations, conflicts and complementarities.

1.2. THE CONTEXT AND UNIT OF ANALYSIS

The empirical research focuses on these knowledge networks in the ICT manufacturing sector in Brazil. Giving the increasing importance of the BRIC[2] economies in the global division of innovative labour, detailed understanding of the characteristics of the Brazilian ICT innovation system is relevant to the historical understanding of the spread of technological capabilities worldwide and how this large country has actively engaged to advance its position in the global ICT industry.

It takes as a starting point, the specific incentives created for the development of innovation projects implemented in the manufacturing sector. Acknowledging the need to retain and expand technological capabilities after the end of import substitution policies in the early 1990s, specific incentives to collaborate with innovation activities where created to support high levels of investments in innovation in companies manufacturing locally ICT products[3].

The previous import-substitution regime was substituted by tax incentives to the commercialisation of a set of industrialised products in the internal market conditioned to local manufacturing and investments in R&D. The change in the institutional framework meant a disruptive transition from the previous national innovation system. In previous phases, the investments in telecommunications were largely controlled by the state or undertaken by national companies that had privileged access to the internal market.

Under the new tax regime, the responsibility for the investments was transferred to companies in the form of required R&D expenditures as a condition to waived taxes on products sold inside the Brazilian market. Generally, this tax regime promoted an overall private investment of more than USD 2 billion in innovation between 1993 and 2005.

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[2] BRIC is a increasingly used acronym referring to large emerging economies: Brazil, Russia, India and China

[3] Under the Brazilian legislation, the ICT manufacturing sector was defined in a relatively broadly sense in order to account for interdependencies and linkages spanning over computers, telecommunications equipments and mobile handsets. It just includes national and foreign manufacturing firms with a certified level of local production.

Despite incremental changes throughout the years[4], the "ICT Law" became increasingly legitimatised inside the sector and it has been extended until 2014. More than 200 companies and another 200 universities and research institutes have benefited from the institutional framework.

These innovation projects allowed, under the framework ranged from infrastructure, training in new technologies, technological services, process and product development in related technological areas and research based activities. The aim of the innovation projects could be chosen unilaterally by the individual companies as long as they could be characterised as R&D activities inside a wide definition. Inside the established rules, a number of restrictions were defined in order to guarantee that at least part of the projects would be conducted in partnership with universities and institutes with a clear intention to support university-industry linkages and possible knowledge spillovers. Structured reports with details of the innovation projects conducted needed to be submitted to the Secretary of Informatics Policy in the Ministry of Science and Technology (SEPIN/MCT) where these reports were audited.

Incentives to innovative activities and networking with education and technological institutes were granted to companies manufacturing ICT products with considerable knowledge content. This institutional framework promoted a large number of decentralised projects, and therefore, tacit knowledge, social connections and decentralised governance structures in the sector. However, as the market became more and more integrated into global value chains, a small number of multinational companies became the key-players in the Brazilian market. For instance, for the period between 1997 and 2003, more than 70% of the total investments were conducted by the top 15 subsidiaries resulting in a context where the sectoral system was largely driven by the subsidiaries' technological activities.

The case of the Brazilian ICT Law, therefore, provides a natural experiment (i) to explore the formation of knowledge networks in developing countries, (ii) the contribution of MNC's to the flow of knowledge between the MNC and partners in emerging economies

[4] Most of the values presented in this document are in Brazilian Reals. See Annex 7 for the historical conversion rate between the Brazilian Real and the US Dollar. Conversion of all numbers to US dollars was not considered adequate as there was a considerable volatility in the exchange rate during the period. As most of the R&D costs are related to Human Resources and other local activities, the conversion could distort the analysis.

and (iii) the institutional attempt to promote the integration of local and global knowledge networks.

Despite the large number of projects, a number of challenges remain for aligning national and international production networks in the sector (Campos & Teixeira 2004; Queiroz, Zanatta & Andrade 2003; Schjolden 1999; Tigre et al 2001; Worden 1997). Rather than a linear process of accumulation of technological capabilities, the knowledge flows involved multiple levels of governance among different stakeholders, resulting in suboptimal organisational structures. This thesis proposes a framework to discuss the sustainability and failure of the project-based knowledge networks and to discuss the balance between interests of different stakeholders in the sector.

1.3. RESEARCH QUESTIONS

The underlying assumption of this thesis is that the examination of the underlying organisation in innovation projects can inform the policy interventions and organisational development in the sector. In particular, this analysis can be useful to understand the different knowledge networks and the diffusion of knowledge between multinational companies and technological partners. Identifying the characteristics of the organisation of innovation in the knowledge networks is relevant for addressing the institutional learning at the network level and the interventions that would promote knowledge spillovers[5] in the sector. The focus of this thesis is the linkages between innovation projects involving subsidiaries and dynamics in the knowledge networks between multinational companies and host country innovation systems. The central question could be stated as: *How does the underlying organisation of innovation projects in subsidiaries promote the sustainability of the knowledge networks formed between multinational companies and sectoral systems?*

In order to conduct the analysis, this thesis focuses on five questions exploring the connection between the micro analysis of innovation projects and the meso-analysis of knowledge networks. These different dimensions can be associated with specific questions:

[5] Although there are many other mechanisms of knowledge spillover such as labour market and informal relationships, we limit our analysis to possible spillovers derived from the collaborations in innovation projects in specific.

- *Organisational Boundaries – How do organisations balance in-house R&D and external knowledge acquisition from technological partners such as universities and technological institutes?*
- *Functional specialisation – What are the patterns of specialisation in the sectoral knowledge networks (i.e. foreign and domestic companies, educational and technological institutions, public and private organisations)*?
- *Collaborative activities - How do inter-organisational linkages emerge and change over time?*
- *Underlying configurations - Which are the common patterns of organisation of innovation projects underlying the knowledge network?*
- *Aims of different actors - How would different stakeholders benefit from knowledge and financial flows in different configurations?*

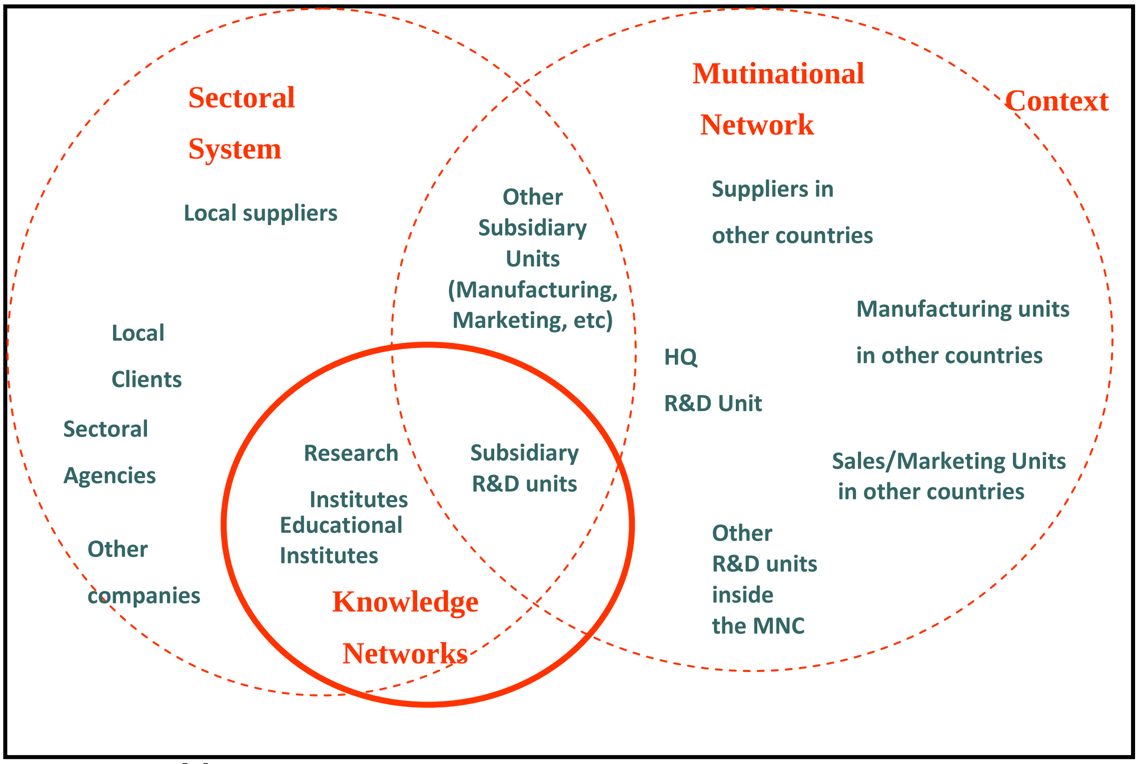
These five specific research questions on the project-based knowledge networks will be used to explore the integration between multinational companies and sectoral network of educational and technological institutes.

1.4. SCOPE, LIMITATIONS AND BOUNDARIES

It is also important to consider some boundaries and limitations of the study. There is a proliferation of studies in the recent literature that use networks to discuss knowledge-related interactions inside groups, firms and sectors. Some of the terms are innovation network (Frenken 2000; Zander 1999a), networks of innovators (DeBresson & Amesse 1991; Powell & Grodal 2005; Soh & Roberts 2003) , learning networks (Bessant & Francis 1999; Teixeira, Guerra & Ghirardi 2006), knowledge networks (Hansen 2002; Owen-Smith & Powell 2004; Seufert, von Krogh & Bach 1999), project networks (DeFillippi & Arthur 1998; Sydow & Staber 2002) and R&D networks (Birkinshaw 2002; Hagedoorn, Cloodt & Van Kranenburg 2005). Although there are differences among these concepts, they are also used interchangeably.

This research focuses primarily on the project-based networks formed between subsidiaries of multinational companies and their technological partners (particularly, research institutes and educational institutes). It examines the interaction between this core group of actors and their interaction with other elements inside the subsidiary, multinational network and sectoral production systems (Figure 1).

Figure 1 – The unit of analysis - knowledge networks between MNCs and sectoral systems



Source: Own elaboration.

This thesis uses two main data sources. First of all, this thesis uses the detailed data of more than 10,000 projects declared by more than 200 companies[6] between 1997 and 2003. During the implementation of these innovation projects, companies involved another 200 research and educational organisations. The data of these projects allows the investigation of the relationships between firms and technological partners in innovative activities in the Brazilian ICT sector. This large database of projects has a very detailed level of description on the innovative activities developed in-house as well as in partnership with universities and research institutes inside the Brazilian ICT industry. To the knowledge of the author, this is the largest database on innovation projects available with standardised classification among categories of innovative activities and with detailed accounts of participants and transaction among organisations inside projects (more than 35,000 individual transactions inside the innovation projects).

In addition, the analysis of interaction between multinational companies and the sectoral network is complemented with in-depth case studies on the main subsidiaries and research institutes in the sector. A qualitative analysis draws on a total of 35 interviews with 11 key subsidiaries and 11 technological partners in the sector. The patterns of organisation of

[6] This includes only companies that also declared projects with technological partners.

innovation projects between the multinational companies and the sectoral innovation system are complemented with detailed archival data. A multiple case study approach is used to investigate in depth the organisational configurations among subsidiaries of multinational companies and their main domestic technological partners with a wider number of organisations.

The usual configurations are explored in terms of general patterns and how different types of stakeholders benefit other stakeholders in terms of knowledge and financial flows. Despite a certain level of uniqueness in the institutional context, the quality and extension of the collected hard data provides a rich set of inputs for the empirical analysis of project-based knowledge networks and a useful way to develop theory on the formation and development of knowledge networks in developing countries.

The collaborations identified are limited by the available data on innovation projects declared under the incentives to manufacturing companies. By focusing on the innovation projects supported by sectoral policies, this thesis explores in particular, the supply-side of the innovation process. By focusing on formal innovative activities, the quantitative analysis is limited to those knowledge-related activities that required significant investments in innovation, either for knowledge creation or knowledge learning. There are naturally other forms of intra and inter-organisational collaborations that are informal and/or not directly connected with the tax incentives.

This research does not investigate the process of diffusion of ICT products and services in the sector (Pohjola 2003), the creation of new concepts based on the interaction with users (Chesbrough 2006), nor attempt to measure the possible benefits of the diffusion of ICT technologies in societies (Mansell & Wehn 1998). Extending the interviews to a larger number of stakeholders such as clients, national companies and managers in different parts of the multinational could provide different insights on the process. However, this would be beyond the resources available for this research.

In this examination of innovation projects, this framework stresses behavioural aspects rather than techniques applied in innovation projects. In other words, while the techniques used in innovation projects have traditionally been the characteristics of most of the literature discussing projects, the recent literature on project management has acknowledged many shortcomings of the normative, technical project models (Hobday 2000; Lundin & Soderholm 1995).

There is no claim that the results presented here are representative neither of the overall pattern of innovation of the individual multinational companies nor the ICT sector in Brazil. The innovation projects examined in this research certainly do not encompass all the innovative activity in the sector nor account for the total number of formal and informal interactions related to learning and innovation.

This research uses network visualisation techniques, basic methods of network analysis and some basic econometric methods to distinguish characteristics of knowledge network in the sector. However, the research is exploratory in the sense that there is a general preference for including a rich number of quantitative and qualitative variables debated and discussed under the specific historical circumstances. Some propositions and statistical techniques are used as supporting tools and as ways to demonstrate key points of the framework. However, there is no attempt to try to model the dynamic occurring in the network.

It is also important to mention that although there is a substantial use of data generated for administrative purposes inside the specific institutional framework promoting innovation in the sector (known as ICT Law), the direct evaluation of the impact of these policies is not a direct objective of this research. Naturally, by examining the characteristics of the innovative activities in firms and their interactions in innovative activities with other sectoral organisations, this research should contribute to the analysis of how policies induce learning mechanisms in firms and how vibrant sectoral innovation networks can be sustained and promoted (indeed, there is a specific chapter dedicated to this specific aim). However, there is no intention to quantitatively measure this impact and the cost effectiveness of the resources allocated to this aim. Other methodologies such as comparatively analysis or databases connecting these incentives with other sector wide performance would be more adequate to this aim.

1.5. THE ORGANISATION OF THE CHAPTERS

The structure of the document is as follows. The second chapter reviews the literature focusing on two key debates in the literature relevant to this thesis (i) the role of S&T policy in the interaction between foreign direct investments and host economies and (ii) the evolutionary growth of multinational networks and the role of subsidiary development. The third chapter defines the theoretical framework using the concept of decentralised knowledge networks and emerging configurations. The fourth chapter summaries the methodological procedures used in the empirical research. The fifth chapter reviews the studies about the accumulation of technological capabilities in the Brazilian ICT sector, the polemic on the impact of the Brazilian *ICT Law*, and the general characteristics of the knowledge networks emerging in the sector. The sixth chapter details the results of the qualitative tests on the structure of the knowledge networks. This is followed by a behavioural examination of these networks in the seventh chapter, where key configurations are identified and their individual aims and attributes are examined. In chapter eight, the structural and behavioural aspects of the knowledge network are put together in order to explore the organisational characteristics that contribute to sustainability and/or failure in the integration between multinational companies and technological partners in the Brazilian ICT sector during the period under investigation. The final chapter discusses the key implications for the literature, policy recommendations and further areas of research.

2. LITERATURE REVIEW

> *"One cannot be exposed to the main currents of international trade for very long without feeling that any theory which neglected the roles of innovation, scale, ignorance and uncertainty would be incomplete."* (p.191, Vernon 1966)

This chapter attempts to draw together some key contributions from a wide and diverse research literature on the creation and transmission of knowledge in multinational networks and innovation systems, particularly in developing and transition economies. Rather than comprehensive, this chapter aims to contextualise this research inside the wider dynamics occurring inside the increasing internationalisation of technological capabilities and its co-evolution with sectoral industrial networks in developing countries, the role of subsidiaries in promoting knowledge flows between national and international networks and the role of innovation policies in developing countries that are facing increasingly open economies.

This chapter is divided into two main sections. The first part of this chapter discusses the frameworks used to investigate the interaction between foreign direct investments and host-country economies. It starts with some of the evidence of and limitations on the traditional frameworks applied to the analysis of the impact of the FDI in general, and in R&D-activities in particular. This is followed by a presentation of the innovation system approach as an alternative framework and the adaptations proposed in the recent literature to account for the peculiarities of developing countries in their interaction with international production networks.

The second part of this chapter focuses on the changing nature of multinational companies. It starts with an introduction to the relevance of the decentralisation of innovative capabilities in multinational companies and the opportunities opened for developing countries. This is followed by a review of the role of subsidiaries in the evolutionary growth of multinational companies and flows of knowledge between the multinational company and the host country. This section concludes with a brief review of the specific role of information and communication technologies (ICT) as a central element in the current reorganisation of production systems as well as the implications of the emerging forms of organisation to developing countries.

2.1. THE INTERACTION BETWEEN MNCS AND HOST-COUNTRY INNOVATION SYSTEMS

This section briefly explores two large streams of literature related to the interaction between MNCs and host-country innovation systems. First, it focuses on the more traditional economic literature discussing its main findings about the impact of Foreign Direct Investments in developing countries, highlighting the role of R&D activities in particular. This is followed by an examination of the literature on innovation systems and their usefulness and limitations in framing the investigation of the interactions between multinational companies and sectoral innovation systems in developing countries, and their recent use in discussing the interaction with multinational companies.

2.1.1. Technological capabilities and the latecomer subsidiary

According to a resource-based view of the firm (Penrose, 1995, Nelson and Winter, 1982, Teece, 1994), firms are composed of firm specific capabilities and routines that define the opportunities and strategic alternatives available to the firm. Teece (1994) asserts that the competitive advantages of firms arise from the possession of technological capabilities and efficient coordination with complementary assets/capabilities. Although technological capabilities tend to have a central role in defining the firm, complementary capabilities are no less important for a firm's comparative advantage. Complementary capabilities are defined as those capabilities or assets that are required to be utilized in conjunction with a specific innovation so that it is valuable to the user. In weak appropriability regimes, firms that control the necessary specialised assets – such as marketing, distribution, manufacturing, and /or after sales service technologies – will be in a position to leverage these assets to capitalise on another firm's innovation and gain a dominant market position. Additionally, financial assets such as a firm's cash position and degree of leverage and locational assets, such as natural resources or cluster specific assets, may have strategic implications.

Routines that interconnect technological and complementary capabilities evolve under the influence of external forces giving room for complexity and path-dependency with a large scope for different organisation forms(Cohen, 1996). Firms develop routines, and learning by repetition and experimentation enables tasks to be performed better and more quickly. In the changing context where new production opportunities need to be identified in individual and organisational level dynamic routines related to innovation, reconfiguration and transformation become especially relevant.

Although this principle applies to any type of firm, the moment of entrance of a latecomer firm may determine and limit the latecomer growth in the development of incremental learning. In general, empirical studies show that latecomer firms faced at least two important competitive disadvantages given the backwardness of its environment: their distance from the major international sources of innovation and R&D; and their distance from advanced markets and the user-producer links essential for innovation (Hobday, 1995). The result of these characteristics is a distinctive nature of the catching-up process.

Different authors argue that firms follow an inverse path in the accumulation of technological capabilities: from learning to innovation (Bell and Pavitt, 1993; Hobday, 1995). While, the traditional managerial literature shows that the leader and follower compete by accumulating technological capability and expanding their complementary assets inside a technological paradigm, the latecomer firms interconnect their assets to international assets in relatively mature industries and learn by accumulating technological capabilities.

The pattern of technological capabilities accumulation from complementary capabilities such as sales and production towards more advanced technological capabilities (e.g. distinctive technological fields) has been observed in many cases as a gradual process based on effective learning mechanisms in a substantial time span (Amsden 1999, Figueiredo 1999, Ariffin 2000). In general, this accumulation of technological capabilities is classified according to degrees of complexity: from basic (simple routines - experience based) to intermediate (adaptative and imitative) to advanced (innovative and risky). A vast literature has observed learning strategies used by the latecomer firms to overcome the initial substantial hindrance and to constantly upgrade and create growth trajectories.

In the literature related to economic development, the technological capabilities have also been placed at the centre of attention (Lall, 1992). According to this literature, the aggregated accumulation of technological capabilities is important to the diffusion of new technologies as they jointly define the ability to choose, implement and exploit new economic opportunities.Lall suggests that the development of capabilities is the outcome of a complex interaction of incentive structures. The different authors argue that the technological ladder provides a general framework to discuss the technological accumulation path, but it does define the mechanisms and incentives that promote constant upgrading of firms.

In this context, the potential contribution of subsidiaries of multinational companies in the accumulation of technological capabilities in a latecomer context is considered particularly complex. It has been observed that the internal hierarchical, vertically integrated transnational firms have ‘fragmented’ into ‘diverse’ networks, reintegrated through information technology (Haagedorn and Narula, 1995). The international FDI in the form of merges and acquisitions, green field investments or the simple reinvestment of profits in dispersing subsidiary entrepreneurship, create opportunities to interconnect large numbers of local and global technological capabilities. Making use of this network, subsidiaries may behave similarly to “latecomers” and exploit local technological and complementary assets and evolve some of the products, even coordinating world mandates.

In order to exploit the evolution of the subsidiary’s local technological and complementary capabilities, some relative countries have successfully developed incentives to integrate subsidiaries in the technological transfer and the accumulation of technological capabilities required for competing in global economies. However, new forms of governance between the multinational networks and the local economy seem to be required in order to ensure the necessary incentives for constant learning and upgrading. However, given the characteristics of the MNC's established structure and strategy and the technological endowments of the subsidiary environment, the accumulation of technological capabilities does not naturally occur in most of the developing countries.

In this context, the further understanding of how multinational companies contribute to the knowledge flows in the the host country remains a key empirical issue explored both in the economic and managerial literature, as discussed in the following sections.

2.1.2. Foreign Direct Investments and knowledge spillovers

Few topics provoke so much controversy in different political arenas as the impact of foreign direct investments in developing economies. On one hand, it is argued that the multinational corporation (MNC) represent much more than the simple import of capital into a host country and because of the possibility of significant increases in productivity, it is fundamental to integrate global economies. On the other hand, foreign companies are also seen with very suspicious eyes from host country firms and politicians, as they can drain resources and market opportunities without addressing long-term developmental needs. This section examines briefly what the recent economic evidences tell us about the impact of FDI in host economies.

Although the economic literature on the internationalisation of MNCs and the possible impacts in the host country have been a focus of theoretical debate for decades

(Gershenberg 1987; Globerman 1979; Mansfield & Romeo 1980), the empirical literature on the topic has exploded in the last decades. The initial studies on FDI spillovers were mainly based on case studies and theoretical models that guided theory development. The initial literature pointed out that horizontal and vertical linkages, labour turnover and demonstration effects were important mechanisms of spillover (Blomström 1986; Caves 1974; Hymer 1960; Vernon 1966).

Their argument for promotion of FDI could be briefly summarised in three main areas (Blomström 1997). First, most of global R&D is concentrated in MNCs, therefore the presence of subsidiaries would provide a way for the host economy to have access to technology that would not otherwise be available on the domestic market. Secondly, the presence of subsidiaries of MNC and the introduction of new products would result in the diffusion of information, reducing the uncertainty about cost and opportunities from new technologies and therefore promoting the adoption of new technology by local competitors. Thirdly, the market in which multinational companies operate is usually characterised by high barriers to entry, high concentration and imperfect competition. A limited number of local players would have the financial and technological capabilities to compete with the scale economies, high initial capital requirements, intensive advertising and advanced technology.

Many scholars advocated the advantages of foreign direct investment to the host countries. Formal economic models suggested the importance of FDI as a technological transfer mechanism that could bring about the redistribution of world income (Krugman 1979; Wang 1990), a reduction in the technological gap (Findlay 1978) and an acceleration of local innovation and economic growth (Grossman & Helpman 1991).

These types of argument supported market liberalisation policies across the developing world. During the peak of the liberal reforms in the early 1990s, policy recommendations for growth in developing countries focused almost exclusively on macro-economic stabilisation and trade liberalisation. Openness to trade in general and FDI in particular, became key parts of the most traditional recipes for growth - broadly identified with the term "Washington Consensus"[7].

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[7] The term Washington consensus was first used by John Williamson. The term became associated with a common set of policy reforms that most Washington institutions (World Bank, IMF and others) thought would be good for Latin American countries in the early 1990s. The reforms involve fiscal discipline, redirection of public expenditure towards primary health care, primary education, and infrastructure, tax reform, interest rate liberalisation, a competitive exchange rate,

Despite the general belief that FDI would introduce new technology domestically, the empirical studies on possible productivity increases resulted in mixed evidences showing that the technological spillover process was not automatic. As databases started to be constructed in recent years, a vast literature has emerged attempting to quantify technological spillovers and the role of multinational and domestic countries in terms of their relative contribution to the host economy (for a more detailed review, see Iacovone & Perini 2004). (Bell & Marin 2005; Blomström 1992; Blomström, Lipsey & Zejan 1994; Blomström and Wolff 1994; Branstetter 2000; Breschi & Lissoni 2001; Kokko 2000; Tybout 2002; UNCTAD 1999). The empirical evidence shows that openness was not enough in itself to solve the technological needs of the host economies (Williamson 2000).

Despite some overall positive results, mixed evidence and criticism of assumptions used on the liberal recommendations started to pile up. The limited knowledge spillover observed in some developing countries (especially in Latin America and Africa) showed a larger set of requirements would be necessary in host countries willing to maximise the inflows of technology through foreign multinationals (Deardorff & Djankov 2000; Görg & Greenaway 2004; Haddad 1993; Harrison 1996; Kokko 1994).

The initial explanation of the lack of spillovers in many developing countries is that domestic firms may not have enough *absorptive capacity* to internalise the possible benefits derived from the introduction and expansion of FDI (Cohen & Levinthal 1990; Keller 1996; Narula 2003). The literature started to point out the importance of the learning efforts of host-country firms (i.e. absorptive capacity), as a requirement for increasing the rate at which MNCs transfer technology. For instance, recent empirical studies show that firms with greater absorptive capacity, as measured by prior investment in research and development, and firms with highly educated employees benefit more than others (Gertler 2002).The literature has argued for the need to reduce the technological gap between foreign firms and domestic companies through specific incentives (Glass & Saggi 1998).

A more recent perspective is that knowledge spillovers will only be possible if subsidiaries incorporate high technological content activities such as R&D activities inside their local

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trade liberalisation, liberalisation of inflows of FDI, privatisation, deregulation and secure property rights. Later this term became associated with neoliberalisation and market fundamentalism.(Williamson 2000) activities (Dunning 1994). The empirical debate re-emerged recently with the increasing rate of internationalisation of R&D activities inside multinational corporations (Cantwell 1995). Although R&D activities were initially assumed as a case of non-globalisation, at least in terms of knowledge creation (Patel & Pavitt 1992), the recent empirical results show that the increasing internalisation of R&D is enabled by the technological advances in ICT that opened opportunities for multinational companies to develop global knowledge networks and tap into geographically disperse capabilities and competences (Granstrand 1999). The argument is that innovation increasingly needs constant access to international knowledge and inward and outward FDI in R&D is probably the most direct way to connect with centres of knowledge in other countries (UNCTAD 2005).

The R&D activities inside subsidiaries have been increasingly recognised as fundamental in order to make the most of the possible technological spillovers from multinational companies (Bell & Marin 2005). Attracting and cultivating the development of high value-added R&D activities became a desired object by developing countries that identified an opportunity to use these knowledge networks to tap into increasingly complex technological knowledge which provide the basis for international competition (Kokko 1995).

Recent policy recommendations have argued that latecomer economies should use these established knowledge networks in order to access the technical knowledge and skills from the leading economies (UNCTAD 2005). At the same time, the review of economic evidence shows that the risk of shallow integration requires host countries to make specific efforts to attract and promote the accumulation of technological capabilities (Radosevic 1999a{Keller, 1996 #1382). Most likely, a combination of incentives to develop the absorptive capacity in local firms, technological activities in subsidiary and a number of intermediate institutions are complementary requirements for reaping benefits from the integration into global economies.

Despite the increasing competition between countries to attract high-valued added activities, there is a recent trend in the literature, arguing that it is necessary to shift from the focus on attracting FDI (even high valued added FDI) to a perspective on cultivating a balanced development of knowledge activities inside subsidiaries and promoting linkages with host-country firms and intermediate institutions. Different forms of joint ventures, strategic alliances, subcontracting arrangements and inter-governmental cooperation are used by firms and countries as avenues to create or promote innovatory capacity. All these different mechanisms have their own particular costs and benefits for the participants (Dunning 1994).

At the moment, the traditional methods of economic analysis lack the "resolution" to identify the key conditions necessary for sustaining knowledge spillovers in developing countries. Certainly, the existing methods for discussing these costs and benefits remain very limited. Decisions concerning which type of interventions would be most appropriate in transition economies need to be taken under considerable consideration.

Therefore, new methods and framework are necessary to identify the structure of knowledge flows in sectors in developing economies. New methods should acknowledge the increasing importance and opportunities opened by the ICTs to integrate and coordinate the knowledge creation and diffusion in between countries and organisations. Although certainly not complete, a framework based on innovation projects among local firms, subsidiaries and intermediary institutions could be a useful contribution towards a more systemic analysis of the knowledge spillovers in sectors.

2.1.3. Sectoral innovation systems in developing countries

The literature on innovation systems discusses organisational learning in key actors, interaction between domestic and global production networks and the differences in institutions ranging from macroeconomic policies to business practices. In recent decades, innovation systems gained huge popularity as frameworks to analyse and compare countries and sectors in terms of their institutions, agents and networks and knowledge base.

The elements of this framework were first used to examine nationally (Freeman, 1987; Lundvall, 1995). Freeman defined it as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies" (1995). Lundvall conceptualized it as "the elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge ... and are either located within or rooted inside the borders of a nation state" (1992). Metcalfe interpreted the original concept as the "set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts which define new technologies." (1995).

Later, the concept of innovation systems was adapted to discuss innovation within different geographical boundaires. For those interested in sub-regional categories, the concept of a regional innovation systems (Cooke, Gomez Uranga & Etxebarria 1997) became increasingly used. A regional innovation system made reference to those institutions and organizations that encourage the rapid diffusion of knowledge within a geographical area larger than a city, but smaller than a nation. In an even smaller geographic area, the concept of local innovation system was applied even to refer to local innovation systems.

The concept also has specific applications to discuss specific technological and sectoral dynamics. These approaches usually refer to the original work of Dahmen and his research on the development of different industries in Sweden in the interwar period and how it influenced the formation of a broad set of interconnected producers and users of products (Dahmen, 1988). Although he did not use the concept of the innovation system, he pointed out how specific advantages in different sectors (such as pulp and energy) were developing interactively, often with the aid of knowledge-producing organizations. These intersectoral chains of production were called 'development blocks' and one block would include, in its most complete form, a whole chain of production, as well as independent sources of knowledge that would be involved in interactive learning.

These dynamic principles already included elements of the current conceptualization of Innovation Systems when reference was made to sectors and technologies. A Technological Innovation System can be defined as 'a dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilisation of technology' (Carlsson and Stanckiewicz, 1991). Similar to other approaches, the analysis attempts to grasp the dynamics of the system as a whole, with a particular focus on how individuals and organizations take advantage of the technological opportunities, even when operating under bounded rationality.

Similarly, Malerba (2005) proposes that sectoral innovation systems can be analysed based on their (i) knowledge and technologies, (ii) actors and networks and (iii) institutions. 'Knowledge and technologies' refers to the knowledge base, technologies and inputs that characterize each sector, including the innovations that dynamically transform the sector over time. 'Actors and networks' refer to the range of heterogeneous agents that are organizations or individuals, including, in particular, firms and non-firm organizations, and their market and non-market interactions. Finally, ‘institutions’, include the different norms, routines and common habits, established practices, rules, laws and standards influencing the behaviour of actors and their interaction.

Sectoral innovation systems (Malerba 2002) have been used to examined the networks of organisations and institutions in developed economies. It is argued that by simply considering this complexity, meaningful interventions and learning in sectoral settings can be conceived of and proposed as part of the developmental process. This approach has the potential to advance our understanding on: (i) the heterogeneities among firms within a sector and the structure and change in the relationships among agents, as well as the differences in the role of sectoral institutions, the processes of variety creation and selection, and co-evolution.(ii) the patterns and regularities in terms of elements, structure and dynamics among sectors, (iii) history friendly models of the industrial dynamics that could be confronted with empirical data, and (iv) public policy proposals that could provide insight into how to better affect the transformation of sectoral systems, the innovation and diffusion processes, and the competitiveness of firms and countries. The different approaches and conceptualizations of innovation systems have been useful to focus on different parts of the system, and, therefore examine the complex and dynamic sectoral coevolution from different perspectives. Although it is not a prescriptive theory, the different elements of the general framework have shown its importance in practice. An innovation system perspective may help to identify mismatches and blocks that parts of the system exert on the rest. In addition, it may provide relevant recommendations to help overcome vicious cycles that hinder systems in their growth, development and transformation.

In addition, although most of the studies using the innovation systems have been carried out in developed countries, the innovation systems approach has been increasingly used to discuss aspects of technological catching-up and transition economies (Cassiolato, Lastres & Maciel 2003; Cimoli 2000; Kim 2000; Viotti 2001; von Tunzelmann 2004). These authors argue that the organisation and production process developments that have characterised leading firms cannot simply be replicated in the newly industrialised countries. Case studies of the role of specific organisations and programmes in the absorption and adaptation of foreign technology and the development of the local industry have become one of the key building blocks in this stream of research.

Giving the absence or fragility of systemic relationships among countries in developing countries, the examination of sectoral innovation systems in developing countries is increasingly intertwined with the understanding of the Penrosian evolutionary growth of firms, placing learning at the foundational level as the key component in the catching-up (Amsden 2001; Amsden, Tschang & Goto 2001; Hobday 1995; Lall 1997). The accumulating technological capabilities have been widely recognised as a key criteria of performance in the micro-level organisational of innovative activities (Amsden 2001; Ariffin 2000; Dutrénit 2004; Figueiredo 1999; Hobday 1995; Kim & Dahlman 1992; Lall 1987).

These authors point out that the innovation system approach requires some adaptations when referring to developing countries. It is recognised that the analysis should pay special attention to how the globalisation processes affect the possibilities to build systems of innovation in developing countries and in local systems. In addition, possibly more than in other cases, potential conflicts between interests of the different stakeholders in the innovation process need to be acknowledged (Lundvall et al. 2002; Mani 2004b). In the transition to open economies, an understanding of the possible misalignments between the governance of foreign and domestic functions, and between the macro, the meso and micro levels is required(Kim & Tunzelmann 1998; Radosevic 1999b; von Tunzelmann et al. 2004).

The analysis of sectors that successfully accumulate world class capabilities shows a large repertoire of strategies that were used by host countries to intervene directly or indirectly in the evolution of R&D related activities in multinational companies. For instance:

- Many governments put considerable emphasis on creating communication infrastructure and investing in local development of human resources, making companies' comparative advantages directly connected with a set of fixed assets that cannot be removed from the specific location (Dunning 1994).
- Agencies are created to negotiate linkages between subsidiaries and local companies, research institutes and technological parks in an attempt to promote clusters and/or agglomeration economies (Best 2001; Porter 1990, 1998).
- Subsidiaries' managerial entrepreneurship is promoted to encourage the consequent acquisition of global mandates (Birkinshaw 1996; Delany 1998; Giarratana, Pagano & Torrisi 2004)

- Formal technology transfer requirements and performance requirements are used by many developing countries (Bell 1996). Some of the options inside this category have become unavailable for countries joining the WTO.
- There is widespread use of investment agencies focusing on attracting the FDI, in general, and in R&D. In some cases, they center mainly on providing information. In others, they are mechanisms to negotiate benefits, goals and contracts with multinationals (Amsden & Cho 2003; Morisset & Andrews-Johnson 2003).
- Many countries use some form of subsidies and tax incentives to corporate R&D investments (Hall & Reenen 1999). Although they vary from more horizontal incentives to specific sectoral policies, they are still largely accepted in international trade agreements.
- In some cases, particularly in China, the strong role of corporate law forces joint-ventures with local partners. In many cases, these requirements have been considered too interventionist when compared to the traditional "FDI-friendly" policies (Lo & Tian 2005). Again, joining the WTO may limit this discriminatory behaviour.
- Different forms of public funds are used to promote the absorption and creation of strategic technologies connecting subsidiaries with other actors in the local economy and strengthening the local production system and the integration of local linkages (Inzelt 2000).

The empirical evidence developed in this literature is important in different ways. First of all, it provides enough evidence to suggest that one needs to avoid reductionist views of the implications of the integration between multinational companies and host economies. A brief review of the list above shows that the technological interventions vary from extremely market-friendly to very strong interventionism. In fact, many developing countries suffered considerable coercion to eliminate specific types of intervention as the abolition of some practices became requirements in international trade agreements. The discussion about whether the enforcement of these liberal rules was a means that developed countries found to "kick away the [developmental] ladder" still remains a contentious and popular issue (Frederick List cited in Chang 2002). The sustainable development of technological capabilities is neither the result of free market forces nor the result of the leadership of a nationalistic state.

Exploiting opportunities in the international industrial production and innovation networks has been fundamental in the success of the cases of technological catching-up (Patel &

Pavitt 1991). The historical research has been essential to evaluate alternative organisational arrangements used by catching-up economies in developing their knowledge networks. For instance, the role of keiretzu in Japan and cheabols in South Korea, the networking policies around technological institutes in Taiwan, computer and diaspora networks in India. In each case study, key authors emphasised the role different organisational forms had in promoting the economic catching-up process and overcoming the disadvantages of backwardness in specific circumstances. Different patterns in the knowledge networks may become necessary depending on the co-evolved relationship between the multinational company and the host-country innovation system.

The variety of strategies and results achieved in different cases suggests that rather than assuming automatic knowledge spillovers, host economies need to actively engage in inducing the local learning process through the creation of environmental conditions and organisational mechanisms that would encourage knowledge flows both between the subsidiaries and other actors in the multinational network and between subsidiaries and the local or national actors. The valid assumption is that these inter-organisational mechanisms are necessary to permit local firms and institutions to acquire knowledge created in other regions through the interaction with the multinational networks.

One crucial question however, lies in the extent to which resources should be allocated to specific public policies and initiatives and the measurement of the possible returns of these incentives to the local economy. In many cases, rather than encouraging private investments in innovation, public investments in R&D might crowd out those desirable investments and stifle entrepreneurship. Although some subsidies might target specific groups (small firms for instance), econometric evidence shows that crowding out effects cannot be ruled out (Busom 2000). Evidence in the econometric literature remains largely inconclusive (David, Hall & Toole 2000).

The replication of the ‘best practice’ from most advanced countries is unlikely to have a significant impact on the level and progress of entrepreneurship in developing countries (Altenburg & Von Drachenfels 2007; Hobday & Perini 2006). In the contemplation of the most appropriate position between “strong” interventions and “soft” reforms, an integrated industrial strategy must be considered to achieve scale in learning, or second move advantages, without ossifying the industrial structure. However, despite a wider agreement on the advantages and disadvantages of both approaches, little guidance is still available for decision-makers.

The literature points out that the organisational alignment (fit) between the types of innovative activities, the organisational linkages and the institutions in sectors provide an important source of competitive advantage for firms and sectors (Drazin & Van De Ven 1985; Ghoshal & Nohria 1989; Mintzberg 1989; Nelson 1991; Nelson & Winter 1982).

Unfortunately, most of the literature on innovation systems in developing countries still tends to be based on a presumable linearity in the accumulation of technological capabilities (Lall 1992; Bell & Pavitt 1993). The analysis should acknowledge the *multiplicity* of networks (i.e. global, national and local), that result in the need for investigating multiple levels of governance (Kim & Tunzelmann 1998; Radosevic 1999b; von Tunzelmann et al. 2004). This 'network alignment' involves different levels of multilateral and multi-dimensioned governance to sustain effective coupling between the evolution of the previous national (local) specific systems and the global (regional) production systems.

Multinational companies co-evolve with the host country technological partners (Cantwell & Santangelo 2002; Castellani & Zanfei 2002; Haagedorn & Narula 2001; Criscuolo &Patel 2003; Zander 2002). Therefore, the complex relationship between governance and technology, at both the historical and empirical levels must be explored in depth, and research tools able to examine the systemic interaction among multinational and national actors must be devised. The analysis of innovation systems in transition and developing economies have pointed out the importance of innovation policies to promote a long term alignment between multinational and national production networks (von Tunzelmann 2004; Radosevic & Auriol 1999). Different forms of intervention may be particularly necessary considering situations where there is a low level of capabilities inside local companies and a strong requirement to absorb and appropriate from external sources.

Rather than generic global rules, theorists and practitioners concerned with organisational design need to acknowledge that there is a limited number of context specific configurations that can be applied in individual organisational circumstances. Rather than a simple fit between knowledge, structure and performance, the relationship between these dimensions needs to simultaneously take into account the many possible variables and multiple organisational solutions. Exploring these possible solutions is fundamental to the design of policies that recognise and take advantage of specific organisational and contextual characteristics (Dunning 1992; Kogut 2002; Kuemmerle 1999b; Leonard-Barton 1995). The identification and comparision in greater detail of the patterns emerging in specific sectors provide a useful agenda for the empirical research related to informing organisational design and policy intervention.

2.2. THE CHANGING NATURE OF MULTINATIONAL COMPANIES

Important changes are occurring in the nature of multinational companies and this increases the pertinence of the examination of the interaction between the multinational companies and host country innovation systems. Three particular streams of literature are reviewed in this section. First, this section points to the increasing internationalisation of technological capabilities in multinational companies. Secondly, this section discusses the literature on international management and the increasing recognition of the role of subsidiaries in the flows between the multinational company and host country. Finally, this section reviews the specific characteristics of the ICTs and their impact on the nature of multinational companies and the design of institutions and policies.

2.2.1. The emergence of knowledge networks in MNCs

This section briefly reviews the empirical research on the internationalisation of the knowledge in multinational companies. Until the early 1990s, studies using patents to investigate the innovative behaviour of large multinational companies supported the perspective that innovation was not a decentralised function in multinational companies (Patel & Pavitt 1991). However, decreasing trade barriers and technological advances, especially in ICT, have created new opportunities for host countries to participate in global knowledge networks.

The results of the empirical studies changed during the 1990s, and started to show a trend towards geographical polarisation of innovative activities in certain countries ('triadisation' in Japan, USA and Europe instead of globalisation) (Patel & Pavitt 1998) and, more precisely, in specific regions inside these areas (Cantwell & Iammarino 2003). It became well understood that the evolution of the multinational company is also largely influenced by the technological characteristics of the host country. Specific regions also become less diversified or more narrowly concentrated in their technological specialisation (Cantwell & Janne 1999; Cantwell & Vertova 2004).

Large companies still remain highly centralised although co-evolving with specific technological advantages of the home-country innovation system. Analysis of patent databases suggests that subsidiaries were increasingly embedded in host country knowledge networks and as they matured, subsidiaries increasingly acquired and shared knowledge locally (Phene & Almeida 2003). In the long run, it is understood that at the pace that MNCs and countries' specific technological advantages (e.g. National Innovation Systems) co-evolve, the MNC R&D network operates in function of the geographical hierarchy of regional centres that specialise in different technologies (Cantwell & Iammarino 2003; Zander 1999b, 2002).

The qualitative literature has also observed the behaviour of MNCs in case studies in "peripheral" countries, where the multinational companies expanded their influence on a wide network of suppliers and distribution channels. Rugman suggested a flagship model to be used that would be more appropriate in industries where internationalisation and globalisation is advanced, illustrating important characteristics about the relation between MNC and host country (Rugman 1997): (i) The main firm provides direction and leadership beyond the resources that, from an accounting perspective, lie directly under the flagship's management control; (ii) The flagship firms extend their influence throughout the network in such a way that the quality of business leadership provided by the flagship directly affects the competitive position of the other key actors in the network; (iii) The role of the home government's policy is much less relevant than that of the associated triad government in the extension that smaller economies are drawn into the regional networks of the triad leaders. MNC would increasingly secure their market power and exercise their influence over nascent companies in developing countries.

The recent empirical evidence points to a new phase in the decentralisation of technological capabilities of MNCs. Promoted by the increasing liberalisation of markets and diffusion of ICT technologies, developing countries are deepening their integration in global markets. The ICT industry is a special case where internationalisation of innovative activities inside multinational companies within developing countries is particularly evident. As pointed out by Ernst and Kim, during the 1990s, global brand leaders have outsourced important parts of their global production networks. Companies from North America like HP, Dell, Compaq, Motorola, Intel, IBM, Lucent, Nortel were followed by European leaders (e.g., Philips, Ericson, Siemens and Nokia) and, more recently, Japanese ones (e.g., NEC, Fujitsu, Sony) in the pursuit of divestment strategies (Ernst & Kim 2002). More recently, many incumbents in the telecom industry have perished under the convergence of different digital communication technologies (Gambardella & Torrisi 1998; Yoffie 1997).

Multinationals from the leading countries can catalyse growth in host countries and may even account for a substantial part of the initial accumulation of technological capabilities (Arora & Gambardella 2004a; Athreye 2003). A complex set of linkages is the basis for entrepreneurial action that could result in knowledge spillovers, innovation and growth. The increasing specialisation of the ICT industry has created particularly complex settings, where the evolution in areas such as software, telecommunications and semiconductors have created exponential combinations of incremental, radical and architectural innovation (Henderson & Clark 1990). However, this complex set of complementary capabilities is rarely available in host countries and therefore the vertical and horizontal linkages in latecomer countries lack the necessary diversity.

However, the tendancy towards an increasing division of labour between developed and developing countries may be slowly changing. Empirical studies at country or regional level show that some highly internationalised firms restructured their innovative activities in order to gain advantages of pools of competence in developing countries as well. In addition, many firms have had to undertake substantial organisational changes in order to survive the technological dynamics.

Repositioning themselves in the MNC's value chain became the core strategy of many subsidiaries and countries (Chen 2002a). This process requires the construction of complex social networks and organisational structures able to exploit the opportunities of the new technologies (Hobday, Cawson & Kim 2001).

Naturally, there are still many differences related to the internal characteristics of individual companies. On a firm level, studies show a very high variance suggesting that traditional characteristics such as cheap labour, a market for engineers, proximity to markets, and proximity to the source of technology cannot completely explain the MNC's behaviour (Patel & Pavitt 1998). Thus, there is an important learning process in the subsidiaries that is also responsible for the global R&D decision-making (Hakånson 1992). In addition, "random" factors, such as acquisitions and "unusual" entrepreneurial subsidiary managers play a significant role in the overall R&D decentralisation to make use of the worldwide dispersal of resources in an effective way (Meyer 1992).

Investigating these "random" and "unusual" dynamics is therefore central to the examination of MNC-based technological catching-up processes and still, little is understood about this dynamic. Clearly, a greater understanding of existing structures and punctual contributions of specific initiatives is required. Innovation projects could provide a new and unexplored way to understand this dynamic development of specialisation and interaction in the evolution of international knowledge networks complementing other measurements of internationalisation of innovative activities.

2.2.2. Subsidiaries and the knowledge flows between multinational and domestic networks

The recent literature in international management has increasingly recognised the importance of understanding the behaviour of a subsidiary as an important condition to the flow between the multinational company and the host country. This clearly contrasts with the earlier models of the MNC that assumed a relatively monolithic planning and decision-making process regarding technology. Headquarters would develop most of the innovation and also closely control R&D operations abroad that would support the subsidiaries' absorption of technology and adaptation into different markets (Vernon 1966). Most of the initial literature focused almost exclusively on specific foreign direct investment, but some also alluded to the headquarters' decision to invest in different locations.

These assumptions about the centralised decisions regarding technology in the multinational company, mainly valid in the majority of the cases at that time, were challenged as more complex forms of multinational corporations evolved during recent decades. It has been observed that the headquarter's ability to influence subsidiary strategy cannot be taken for granted (Prahalad & Doz 1981) and companies need to rely on their network of subsidiaries to provide the flexibility to manage this duality of local-global pressures (Ghoshal & Nohria 1989).

In the recent literature, it is widely acknowledged in most of the companies that a level of flexibility at the subsidiary facilitates a better response from the multinational corporations to pressures in the local markets and to the demand to globally integrate activities (Bartlett & Ghoshal 1989; Birkinshaw et al, 2003; Dunning 2000). The function of headquarters became less related to direct control of organisational form and/or technology used and more related to the coordination and alignment of strategic decision making among differentiated subsidiaries (Doz, Bartlett & Prahalad 1981; Ghoshal & Nohria 1989; Kuemmerle 1997; Zander 1998). Therefore, the possible impact of the MNC in the host country started to be discussed more and more in terms of the specific roles played by subsidiaries in the MNC network.

In this direction, the international management literature has been extremely prolific in the development of typologies that could distinguish the role of subsidiaries inside the multinational network. Many typologies emerged to define subsidiary roles in the network. Among the most widely recognised typologies is the distinction between Product versus market scope (miniature replica, product specialist, strategic independent) (White & Poynter 1984), competence versus strategic importance (resulting in the distinction between black hole, local implementers, contributor and strategic leader)(Bartlett & Ghoshal 1989), integration versus responsiveness (locally responsive, integrated product strategy, multifocal strategy)(Prahalad & Doz 1981), knowledge flows and inflows (implementers, global innovator, integrated player)(Gupta & Govindarajan 1991), autonomy and integration of activities (local implementers, specialised contributor, world mandate), and asset-exploiting R&D versus asset-augmenting R&D (respectively, R&D labs responsible for supporting production resources, learning from different markets and R&D labs interacting with leading technological sources) (Kuemmerle 1997; Narula & Zanfei 2003).

Although this stream of research acknowledges that different subsidiaries perform different functions, the general line of the typologies tends to point to one "best role", that particularly benefits both the multinational and the host country. It has been observed that the ability of the subsidiary to accumulate distinct technological capabilities fundamentally depends on specific characteristics of the host innovation system (Asakawa & Lehrer 2003; Frost, Birkinshaw & Ensign 2002; Zahra & Dharwadkar 2000).

This has resulted in increasing competition among countries around the world to create a specific set of incentives and to attract and/or turn existing R&D units in their territory into high-technology centers of excellence and world mandates. However, as pointed out by Kogut, clearer progress could have been made if the literature on multinational companies was less concerned with typologies of subsidiaries and R&D labs and more directly focused on understanding the links between organisational structures and strategic advantage (Kogut 2002).

In other words, the process of change in subsidiary development remained under-explored (Birkinshaw & Hood 1998). The current focus of the literature has been on examining in greater depth the process by which each subsidiary develops their position in the MNC over time and the possible implications in terms of knowledge flows. Entrepreneurship in the subsidiary is increasingly encouraged inside the corporation as a way to achieve a balance between local and global demands (Birkinshaw 1995). At the same time, it is observed that the accumulation of distinct technological capabilities is an important way by which subsidiary managers develop their positions inside the multinational network (Egelhoff 1999; White & Poynter 1984; Zahra & Dharwadkar 2000; Zanfei 2000).

A subsidiary centered view of the multinational development has become particularly important in the examination of the interaction between multinational companies and host countries. Following from a resource-based view of the firm, the literature shows that subsidiary development is limited by the availability of resources in excess of the minimum necessary to produce a given level of organisational output (Jarillo & Martinez 1990; Penrose 1995). Strong mechanisms of control hinder the abilities of subsidiaries to innovate, while excessive organisational slack may result in wasteful experimentation and empire-building (Nohria & Gulati 1996).

Evidence shows that a certain amount of organisational slack is important to reduce conflicts, to allow information processing and to promote political and strategic behavior (Bourgeois 1981). The existence of advanced R&D laboratories in subsidiaries has increasingly become a key element in promoting the flow of knowledge between the multinational sources of technology and the local industry (Birkinshaw & Hood 1998; Ghoshal & Bartlett 1988). Severe resource constraints would tend to be particularly relevant in developing countries, hindering their organizational development.

Another important element discussed in this literature is that even when advanced R&D laboratories do exist, there might be organisational mechanisms isolating the knowledge in the multinational company from the knowledge embedded in the host innovation system. Some authors suggested that the ability of MNCs to act as boundary-spanning vehicles between global and local knowledge is overemphasised (Solvell & Zander 1998). As pointed out by Zanfei, "The development of the MNC internal network relies heavily on, and favors, the growth of external, locally embedded networks, which in turn require increasing degrees of autonomy for decentralised units. This increasing autonomy continuously risks reducing incentives to circulate knowledge between units belonging to the multinational company. Considerable conscious effort is thus needed here too, in order to innovate coordination modes and prevent the whole network from collapsing"(Zanfei 2000).

Empirical studies have shown that unlike simple transmission of operational information, the flows of know-how between units in the network require complex and rich intra-firm communication channels. Knowledge flows would not only depend upon the richness of transmission channels, but also the subsidiary's knowledge stock and the motivational disposition to share knowledge of the originator, as well as the motivational disposition to acquire knowledge, and the capacity to absorb the incoming knowledge from the receptor (Gupta & Govindarajan 1991).

Therefore, there is a need to direct the organisational level towards individual initiatives inside the corporation (Table 1). Technology became an effective way on promote the subsidiary status in the multinational network and the recent literature has increasingly focused on specific initiatives in order to extrapolate some of the characteristics of the knowledge flow inside the organisation (Birkinshaw 1997).

Table 1 - Three streams of research on subsidiary management

Stream	***HQ-subsidiary relationship***	***Subsidiary role***	**Subsidiary development**
Focus on research	Aspect of dyadic relationship between subsidiary and HQ	Internal, corporate and environmental factors explaining different subsidiaries roles	Changes in role and activities of subsidiary over time
Assumptions about nature of MNC	Hierarchy: subsidiaries are controlled by HQ	Heterarchy/network: subsidiaries have different roles, and have relationships with multiple units inside/outside the firm	
Research approach	Cross-sectional / Static		Longitudinal/dynamic
Theoretical foundations	Transaction cost theory, contingency theory	Social network theory	Evolutionary theory, resource-based theory

Source: Adapted from Birkinshaw (1998c)

The recent literature has focused extensively on the examination of the knowledge flows inside the Multinational Corporation and, following evolutionary principles, the identification of the way organisation and strategy emerge in the ensuing interactions with the network in the host knowledge network. Inside the subsidiary development literature, the multinational development is driven by the managerial dispersed corporate entrepreneurship. In this context, project-level analysis is increasingly recognised as the most adequate level to investigate how knowledge can be created, shared and used to improve organisations (Kogut & Zander 2003).

Undoubtedly, an evolutionary and resource-based view of the subsidiary development provides a fruitful framework to investigate the interaction between multinational companies and host economies. Nevertheless, there are still a very limited number of studies exploring and classifying these networks and different knowledge functions. Project-level analysis can help us appreciate the knowledge diffusion inside and outside the corporation (Kogut & Zander 2003; Ruuska & Vartiainen 2005; Cantwell & Mudambi 2005). Given the limitation of existing typologies, classifying the sector-specific patterns in the organisation of innovation can provide richer insights into the interaction between multinational and national innovation systems.

2.2.3. Opportunities and challenges opened by the ICTs

The increasing reduction of trade barriers and the diffusion of information and communication technologies (ICT) provides great potential for accelerating the flows of knowledge of the multinational companies and therefore their role in the interaction inside an increasing global economy. As pointed out by Richard Nelson, different eras are dominated by different fundamental technologies and nations require a set of institutions compatible with and supportive of them to be effective with those technologies. The institutions suitable for an earlier set of fundamental technologies may be quite inappropriate for the new technologies (Nelson 1994).

A large number of authors concur that the networks formed by ICT are largely responsible for crucial changes in economic, organisational and political spheres (Castells 2000). Information and communication technologies are fundamentally changing the organisational principles that were the basis of previous phases of market and managerial capitalism (Chandler 1977). Despite some dispute on the specific role of ICT as the determinant of long business cycles, (Freeman & Perez 2000; Perez 2001), there is little doubt in today's world that the successful use of these technologies result in extraordinary reduction in costs associated with microelectronics, telecommunications and electronics computers, resulting in powerful effects in almost every branch of the economy (Freeman & Soete 1997b).

Some authors argued for the enormous potential of information and communication technologies to reorganise the society (Castells 2000), the rivalry and collaboration among companies (Gomes-Casseres 1996) and the production of knowledge (Antonelli, Geuna & Steinmueller 2000). The changes promoted by ICT have resulted in fundamental changes in the organisation of society and the distribution of power among different social groups. Certainly, acquiring sufficient capabilities in ICT seems to be a requirement for any society interested in exploring new paths of development. As pointed out by Steinmueller, "acquiring ICT-related capabilities is rather like learning a language. Knowledge of ICTs provide a different perspective on the world and enables one to see that certain long-held assumptions are simply rather peculiar habits of thought.[...]. As from any new fundamental technology, the gains received from such new tools can never be fully anticipated"(Steinmueller 2001).

ICTs have been connected with an entire range of organisational innovations. The ICT industry has always been characterised by a diverse and interdependent knowledge-base ranging from pure research in physics, mathematics and computer science to technological expertise in telecommunication, hardware, software and semiconductors. Despite its great potential as an important source of growth for a number of developing countries, the rate that different countries have learned, absorbed and created value from these new technologies is the result of a complex set of economic, institutional and organisational capabilities. Different forms of inter-firm networks containing complementary organisations such as contract manufacturers, silicon foundries, and R&D consortia have been fundamental in sustaining the technological dynamism of the region (Saxenian 1991).

The ICT technologies result in important changes in the nature of the firm. The internal hierarchical, vertically integrated transnational firms have ‘fragmented’ into ‘diverse’ networks reintegrated through information technology (Haagedorn & Narula 1995). Organisational mechanisms such as Corporate Venturing[8] changes from the traditional 'administrative' entrepreneurship of the R&D group towards a ‘incubative' entrepreneurship of a new venture division. Given the speed of change in the industries, specific firms in the ICT sector substantially change even their specialisation on a project by project basis. For instance, Hewlett-Packard transformed from a medical instrument company to a computer-based one. Similarly, Intel changed from a memory company to a microprocessor firm (Eisenhardt & Tabrizi 1995). Thriving against possible core rigidities, some companies have managed to face the intense international competition and rapid technology evolution by constant adapting. Rapidly combining experience accumulation and experimentation in new areas has been key for many ICT companies (West & Iansiti 2003).

Inside this evolutionary process of the global ICT industries, multinational companies play a key role in complementing and integrating worldwide capabilities. ICTs facilitate the integration of geographically dispersed operations and allow networked coordination to replace ownership and hierarchy as a primary mode of production by a single large firm. As pointed out by Pavitt (2001), rather than being built into large companies or independent entrepreneurs, the growth of the firm is determined by increasing networking and internationalisation, stimulated by the quest for knowledge and complementary capabilities. The firm specific paths of development are much more obvious when firms intend to develop new opportunities based on narrow competencies and prior experience. However, successful companies have learned the importance of not simply leveraging existing competencies but also using internal intrapreneurship to learn new ones (Tidd &

[8] Semi-autonomous entity with little formal structure, integration across traditional functional areas, availability of 'patient money', and management support for risk taking and creativity (Galbraith, 1982; Kanter, 1985; Kuratzo et al., 1990; Quin, 1985; Sathe, 1985).

Taurins 1999) and to destroy existing ones. Lessons pioneered by the ICT industry are used by a wide range of companies and industry to learn and promote dispersed corporate entrepreneurship in order to identify opportunities such as the creation of new business activity, to transform or renew existing organisations; and even to change the rules of competition in its own industry (Stopford & Baden-Fuller 1994).

Also, ICTs have important implications for the location of problem-solving activities. On one hand, information is considered increasingly available. ICTs make storage and transference of codified technological knowledge increasingly inexpensive. Large databases of patents, scientific articles and all sorts of information services are increasingly available. On the other hand, often the information used in technical problem solving is “sticky”, costly to acquire, transfer, and use in a new location (von Hippel 1994). The balance between external acquisition of knowledge and in-house development is a particularly complicated case where networks are particularly relevant. Rather than markets or hierarchies, coordination requires a mixture of formal and informal mechanisms that typify a network of relatively independent social elements (Thompson et al 2003). New thinking about the interconnection between global knowledge and adequate sectoral institutions is a requirement of the new techno-economic paradigm.

Despite the increasing availability of information and ever decreasing costs of communication, localised and tacit knowledge developed inside geographically-bound technical communities remains a critical asset for increasing production and diversification in modern industries (Antonelli, Geuna & Steinmueller 2000; Freeman 1991, 1996). Finding new ways to explore the windows of technological opportunities has become a common challenge for government agencies, multinational companies, subsidiaries, universities, research institutes, national companies and the society as a whole (DeBresson & Amesse 1991; Freeman & Perez 2000; Perez & Soete; Powell & Grodal 2005). Cultivating the communities of practice able to transform the technological opportunities into socio-economic change is fundamental for sustaining growth in developed and developing countries.

It is important to highlight that the benefits of ICT technologies are not evenly distributed across societies, or indeed, groups within societies. Some of the key results of the Britain's Programme on Information and Communication Technologies (PICT), comprehensive research on the potential of ICT in society, recognised that the development of ICT is not determined by either technological or social forces(Dutton & Peltu 1996). It is a combination of the processes of both social and technological innovation which influences the course of change, often in unpredictable ways. It may exacerbate the power of specific groups over others or it may reconfigure the decision-making process considering the requirements of a larger number of different groups. As pointed out by Perez, “even the social and political groups who did benefit under recent conditions might find themselves on the losing end if they rely on continuation of past practices” (Perez 1985). ICTs can facilitate the transformation of organisational structures and work practices, but, ICTs cannot be seen as systematically empowering any particular group or privileging any particular structural arrangement (Dutton & Peltu 1996).

For instance, despite the possible shifts in global production determined by the diffusion of ICT, it is not clear whether new forms of e-commerce will redistribute the market power that characterises existing supply chains (Mansell 2001) and whether countries in Asia will establish themselves as the centre of the global ICT industry (Hobday 2000b). It is not clear whether ICT will spread democracies by decentralising decision or autocratic regimes or will increase control and surveillance over citizens (Freeman & Soete 1997a).

Considerable uncertainly exists surrounding the institutional structures that should be used by countries to promote investments in acquiring capabilities in ICT and the ways these investments may pay off in the future. Investigating empirically the reorganisation of global knowledge networks and the concentration and/or distribution of power among different groups is therefore an important question for those societies interested in exploring the windows of opportunities emerging in the reorganisation of global economies.

2.3. SUMMARY AND CONSIDERATIONS

This brief review suggests that despite considerable literature on specific elements, the empirical and dynamic examination of the co-evolution between multinational companies and national innovation systems remains a fundamental challenge for both research and practice.

On one hand, there are limitations of the traditional econometric methods for analysing the interaction between FDI and host country innovation systems. The literature on innovation systems provides an alternative framework, although it has been mainly used to compare the institutional methods used in different countries and sectors. In the developing context, the most relevant questions in the sectoral analysis are longitudinal in nature. Specific configurations could mean lock-ins that might hinder the bottom-up accumulation of technological capabilities inside firms and among organisations. In addition, a large number of questions emerge when subsidiaries of the multinational companies become the centre of sectoral systems. A different role for the S&T institutions needs to be considered in order to build the network that would allow the knowledge flow.

On the other hand, increasingly internationalisation of innovation is deeply connected with the blurring boundaries of firms, sectors and countries promoted by decreasing trade barriers and advances in ICT technologies. Specificly, the literature review shows the increasing importance of breaking into organisational structures to identify the process of interaction among a variety of stakeholders. The behaviour of the subsidiaries is increasingly recognised as a central piece in the knowledge flows between international and domestic context. However, despite the extensive literature in management of multinational companies, there are still limited empirical studies attempting to categorise and measure the evolutionary process occurring at project-level between sectoral systems and multinational companies.

The usual analysis of the foreign direct investments in developing countries still tends to be overly functionalist, considering change as a monolithic process dominated by rational action and neglecting important differences in the agents and their power to influence the directions of technological development. There is a need for integrative frameworks that investigate and measure the underlying knowledge flows in sectors and inform theories in both the multinational companies and in the sectoral innovation systems.

These integrative frameworks need to incorporate dynamic elements. The decision-making is usually constrained by an increasingly complex network of stakeholders marked by path-dependence, uncertainty and bounded rationality. As a wider number of stakeholders are expected to contribute with resources to innovative activities, one must naturally consider the questions related to the engagement with the decision-making process, appropriation of the results of the R&D and the capture of resources and "misalignment" of the structure (i.e. creation of lock-ins).

Given the importance of ICT in transforming the production systems from relative hierarchies towards networked structures, this specific sector is also a major source of interest considering its leading role in the use of these organisational innovations in integrating globally dispersed capabilities. In depth the investigation of the relationships between knowledge bases, governance structures and performance requirements around subsidiaries and their host technological partners can provide insights informing organisational development and institutional design under the current paradigm.

Finally, it is worth noting that studies in developing economies have not systemically examined how the experience with individual innovation projects in subsidiaries is transformed into organisational technological capabilities over time and the resulting network between multinational companies and national systems. This calls for a project-level approach to the analysis of innovation systems in transition that would consider the central role of interaction with multinational companies. Longitudinal studies aimed at understanding the patterns emerging in specific sectors can be particularly relevant for academics, policy-makers and managers of the multinational.

3. THEORETICAL FRAMEWORK

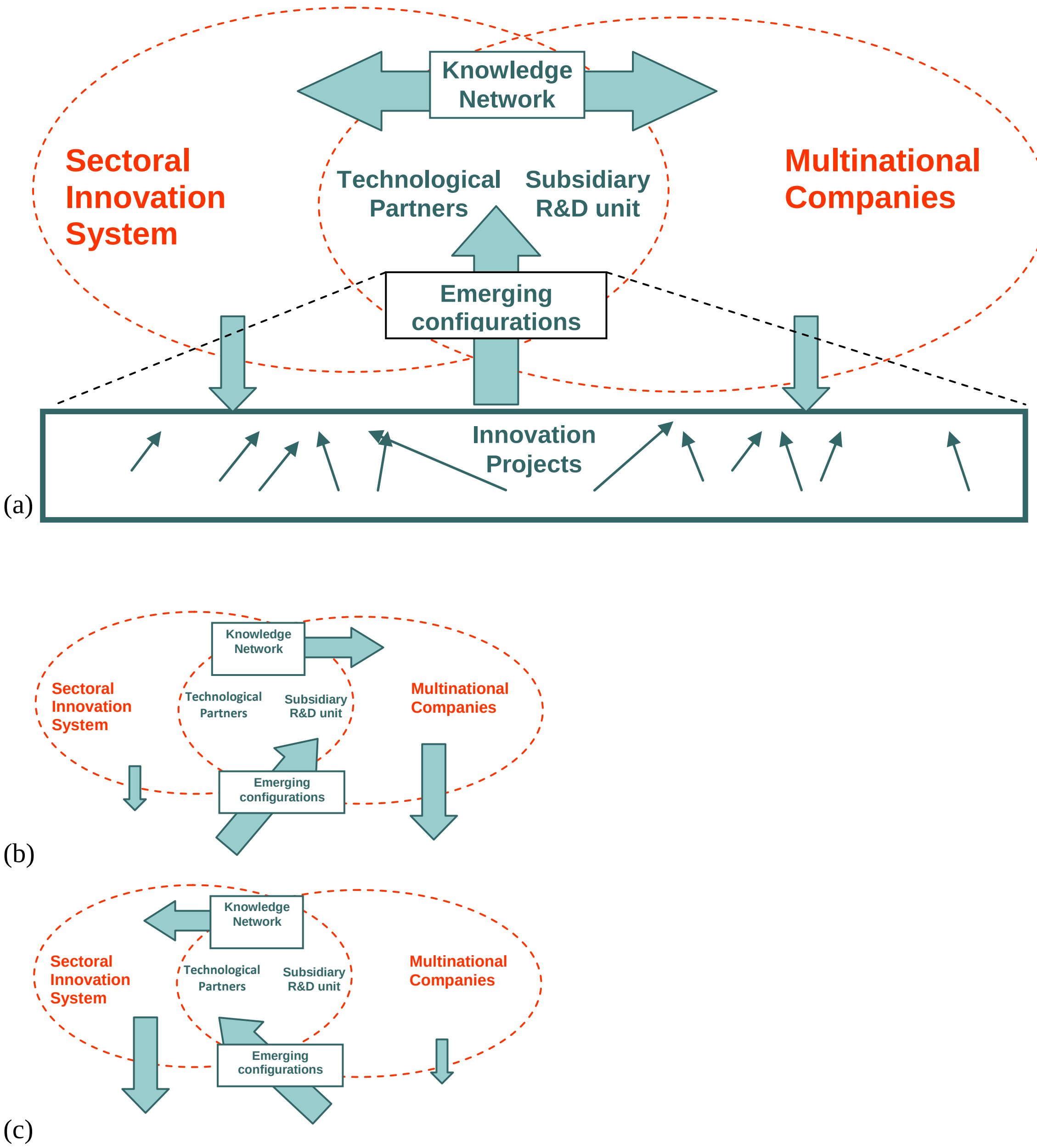
"It is meaningless to study projects in the context of their success or failure, which are only important if viewed as part of a more general process of socio-economic transition. [...] The manner in which the lessons are incorporated into the general policy guidelines depends very much on the ability of the existing institutional structures to undergo the required reforms and take on new practices.(Juma 1986)

As discussed in the previous chapter, different research streams reinforce the fact that successful integration between multinational companies and sectoral innovation systems requires a unique combination of a multitude of governance formats and coordination mechanisms among companies, government, universities and research institutes. However, the literature still provides little guidance on how to investigate the underlying networks between foreign companies and sectoral innovation systems and what is the realistic scope for intervention in specific contexts.

This chapter proposes a theoretical framework for discussing a project level analysis of the dynamic alignment between multinational companies and national networks in sectoral systems. Rather than suggesting general "best practices" in the way that the network between multinational companies and host innovation systems should be organised, this chapter proposes a framework that attempts to characterise the nature of these intra- and inter-organisational networks in order to propose specific strategies and interventions that could sustain the development of the network.

Following evolutionary and organisational principles, the framework proposes that the analysis of the emerging patterns in the network formed by innovation projects provides a useful tool for examining the complex organisational setting between foreign companies and host country innovation system and then suggests adequate interventions. It acknowledges that configurations inside a sector are not totally random and also, strategies and policies are not the result of unilateral decision-making by individual actors. There are a wide number of factors influencing the search, selection and implementation of these innovation projects and consequent formation of knowledge networks. Understanding the existing knowledge network and identifying the configurations emerging among actors involved in innovation projects is central to design adequate interventions.

Figure 2 - Framework for the analysis of the Interaction between Multinational companies and Sectoral Innovation Systems



As pointed out in Figure 2, the framework assumes that innovative projects developed by subsidiaries and their direct technological partners are central to promote a co-evolution between sectoral innovation systems and multinational companies. R&D units in subsidiaries and their direct technological partners are at the core of these knowledge networks providing the organisational channel that determines possible knowledge flows. Responding to influences from the multinational company and the host-country innovation systems, a variety of different configurations in innovation projects will emerge.

The framework assumes that sustainable co-evolution between these two systems would require a balanced expansion of the interactions between these two systems. In extreme cases, the multinational company would be isolated from the sectoral innovation system (Figure 2b), or vice versa (Figure 2c), and the knowledge flows between the systems would not happen. In both cases, the expected co-evolution between two systems would be hindered[9].

Therefore, this framework proposes three key components:

(i) Characterisation of the structural relationships between activities in subsidiaries' R&D units and their direct technological partners;

(ii) Identification of the different emerging configurations developed in innovation projects between multinational companies and sectoral systems;

(iii) Discussion of how specific types of projects would promote the sustainability or failure of the knowledge network

The combination of the analysis of the network structure characteristics and the underlying configurations in the organisation of innovation project provides a useful way to examine the dynamic of the sector in different trajectories and discuss how different strategies can be designed to sustain the dynamic in the sectoral network. This chapter examines the links between innovation projects, knowledge networks and emerging configurations. More specific research questions are elaborated around the expected characteristics of these elements and their co-evolution.

3.1. INNOVATION PROJECTS IN THE ANALYSIS OF SECTORAL INNOVATION SYSTEMS

The idea of using innovation projects as the unit of analysis for examining the creation and diffusion of innovation in sectors is not new. The early studies on innovation focused on developing large databases of the innovations introduced in specific sectors. For instance, in the 1970s, the SPRU innovation database which contains information on 4800 radical innovations in the United Kingdom since World War II, was used to connect individual results of the project to the dynamics of industrial change (Archibugi & Planta 1996; Rothwell et al. 1974).

[9] Following the reviewed literature on sectoral innovation systems (particular network aligment) and the evolutionary growth of multinational companies, co-evolution between these these two systems is considered a normative expectation inside this framework.

In this period, the analysis of individual projects was associated with some advantages and disadvantages. Among the key advantages, it was highlighted that the examination of innovation projects can be a superior indicator than patents in sectors as a large part of innovation does not use this type of intellectual property protection, particularly in developing countries. Even among developed countries, the percentage of innovations for which a patent application is made varies substantially across sectors (The propensity rates for product innovations average 35.9%, varying between 8.1% in textiles and 79.2% in pharmaceuticals). These numbers are probably much lower among innovations introduced in developing economies.

These numbers show that projects can be used to overcome the weaknesses in the indirect measurements of knowledge creation and knowledge flows in companies and sector. Particularly when we move away from the technological cutting edge and traditional indicators of knowledge creation, patents and scientific publications become less reliable (Meyer 2002; Patel, Pavitt & Stoneman 1995).

However, despite the fact that a database on individual innovation provides advantages as they provide a direct measurement of innovations, some authors have claimed that they have substantial drawbacks as well. For instance, the definition of the sample is generally arbitrary, and different people consulted may have different perceptions of the relevance of individual innovations (Archibugi & Planta 1996).

In addition, it is very difficult to develop internationally comparable databases and each of the surveys has used its own design, sample definition and implementation. It is indeed difficult for authors using these databases to claim they have collected a representative sample of the innovation in sectors. In most cases, they may result in a lower count of innovations per company that patent statistics would show. In these cases, other measurements such as patents, publications and results of innovation surveys are more suitable for the analysis of sectors. It is fair to say that the difficulties in accessing reliable and comparable datasets pushed quantitative research on individual innovation projects to the boundaries of the discipline (Archibugi & Planta 1996).

More recently, however, the development of consolidated databases on projects may reverse this trend. Innovation projects re-emerged as crucial ways of organising knowledge flows among stakeholders in complex settings. The quantitative analysis of projects can provide a way to examine how companies reconciled over time the need to exploit and explore technological opportunities (Manning 2005). Different from the concept of capabilities, innovation projects are dynamic in nature as they are more easily defined by its temporary nature and specific aims.

The recent literature on project management and innovation management has reasserted projects as crucial organisational mechanisms for evaluation of new ideas, resolution of problems and translation of knowledge into applied routines (Burns & Stalker 1994; Davies & Hobday 2005; DeFillippi & Arthur 1998; Grabher 2004a; Tidd 1997). Innovation projects are core problem-solving mechanisms in firms and sectors (Dosi & Nelson 1994; Nelson & Winter 1982) and they are directly connected with knowledge-related creation, experimentation and interaction (Dosi et al. 2003; Leonard-Barton 1992). Innovation projects are used by companies both to exploit and explore different knowledge bases for commercial and non-commercial purposes.

Naturally, projects exist in different contexts. In relation to the innovation literature, projects have been used in the analysis of organisational structure in complex product systems (COPS) (Davies & Brady 2000; Gann & Salter 2000; Hobday 2000a; Hobday & Rush 1999) and new product development (De Maio, Verganti & Corso 2002; Eisenhardt & Tabrizi 1995; Hansen, Mors & Lovas 2005; Henderson & Clark 1990). It has been increasingly recognised in the literature that professional communities expand beyond organisational boundaries and are crucial for learning across organisational boundaries (Wenger 1999a).

In addition, the new opportunities opened by the ICT (section 2.2.3) means that innovation projects are not limited to organisational and geographical boundaries. Innovation projects evolve into extended informal and formal R&D networks that acquire a very high level of technical skill in a specialised area. By cultivating a network of R&D partners, firms are able to fulfil sudden or unusual requests quickly and effectively (Brown & Eisenhardt 1995). As expressed by Grabher, “projects hinge on a dense fabric of lasting ties and networks that provide key resources of expertise, reputation and legitimisation”(Grabher 2004a) . Therefore organisational mechanisms need to be acknowledged as more important than proximity in the analysis of knowledge in sectors (Boschma 2005; Iammarino & McCann 2006).

Given their dynamic nature, many innovative organisations make use of a portfolio of projects to balance between exploitation of technological niches and exploration of new opportunities (Davies & Hobday 2005). This research suggests that the examination of innovation projects in different knowledge-related activities can provide in-depth insights into the nature of the knowledge governance in sectors and also, offer a way to investigate evolutionary mechanisms of change inside the industrial organisation.

Indeed, innovation projects seem to be a particularly adequate unit of analysis for the investigation of the sectoral innovation systems in the developing context. Innovation projects are a key mechanism in which interaction among organisations takes place and relevant knowledge for the various parties is constructed and transferred. Innovation projects provide a way to discuss 'relevant knowledge' according to the needs of the parties involved rather than any assumption that the knowledge developed should be new to the world (i.e. patentable knowledge). The analysis of projects provide new ways of measuring the longitudinal evolution of innovation systems in developing countries and compare the governance structures that drive change in specific directions as well as systemic characteristics that may speed up, detain or reverse the formation of these sectoral networks (Bell 2005).

Still, empirical studies are hindered by the lack of reliable databases. The lack of standardisation in contractual relationships and the private and confidential nature of the content make codifying transactions a very complex task in different projects within and among organisations in sectors. However, the increasing use of IT systems and reporting standards provides new ways to scrutinise the decentralised innovation dynamic occurring in sectors. Therefore, secondary data on innovation projects can contribute significantly to the dynamic examination of the knowledge creation and flows in specific sectors.

The possibility of using project level data collected during the implementation of sectoral policies provides a way to connect very closely to the sectoral dynamic induced by specific institutional settings. Although innovation projects have also been used to examine other approaches for the analysis of innovation systems such as national, technological, and regional/local, the current research has as entry point. Although the analysis of sectoral innovation systems is not necessarily linked to specific sectoral policies, this seem to be the most appropriate framework to examine networks formed inside specific sectoral settings as the projects promoted by sectoral policies. Developing the framework for connecting projects to the analysis of the knowledge networks between multinational companies and sectoral innovation systems is central to this research.

3.2. THE KNOWLEDGE NETWORK BETWEEN SUBSIDIARIES AND TECHNOLOGICAL PARTNERS

A necessary initial step in the investigation of the knowledge network formed between multinational companies and sectoral innovation systems is a definition of what is meant by knowledge networks in this research. The term 'knowledge network' may be used as a metaphor to represent the complexity of the innovation process (DeBresson & Amesse 1991), a middle way between market and hierarchy (Powell1990), or even to describe the fundamental nature of the firm and all its economic activities (Coase1937; Williamson 1985).

This research favours a more clear-cut definition of the term. It follows the stream of literature that uses the term 'knowledge network' as an attempt to employ new methodological tools for the analysis of the interactions between agents (Malerba 2005; Powell, Koput & Smith-Doerr 1996; Pyka & Küppers 2002; Wasserman & Faust 1994). Network analysis has emerged recently as one of the most promising tools for the analysis of the knowledge flows in innovation studies. Rather than fuzzy limits, specific rules need to be set a priori in order to define the boundaries of the observable network, its participants and the scope of the observed activities.

According to this literature, knowledge networks could be defined in terms of the broad institutions, the actors, the ties and the knowledge content of the interactions involved in it (Malerba 2005). In the real world, naturally, the limits of the network are seldom clearly defined. However, some guiding rules may be useful to delimit the network's focus of empirical research.

In terms of institutions, the knowledge network is involved in specific institutional frameworks that may be used to determine the boundaries of the network. It is known that knowledge networks depend on supportive institutions to provide the regulative and normative resources within which practices are given meaning (Sydow, Lindkvist & DeFillippi 2004). The sustainability and failure of the project-based knowledge networks is deeply influenced by this institutional framework that operates on different levels usually from organisational practices to national legal requirements (North 1990). Following from evolutionary principles (Nelson 1994), the evolutionary adjustment of institutions to changing technological opportunities and organisations is a fundamental condition for success. Successful institutional frameworks require continued adaptation as the challenges confronting the sector change over time. Institutional learning must be sensitive to the different characteristics of the network and encourage the proper replication of relevant characteristics in specific circumstances. As discussed in the literature on innovation systems, these institutions may be connected to national, regional, supranational, local or sectoral dimensions. In the current analysis, a sectoral dimension of these institutions is particularly relevant (Malerba 2005), as the examination of the knowledge network is related to specific policies applied to the sector.

In terms of actors, it is necessary to distinguish the level of aggregation inside the observed networks. Even the term 'knowledge network' could refer to different levels of aggregation such as: individuals in the labour market (Granovetter 1973); among groups inside an organisation; as well as in vertical (Hardstone 2004) or horizontal relations (Acha & Cusmano 2005) within an industry[10]. This framework focuses on the analysis of linkages among organisations, and in particular, the innovation activities occurring inside and among multinational and national manufacturing firms and technological counterparts such as educational and research institutes in the sector[11]. However, as in any study conducted within the social sciences, any bounded social network is influenced by the behaviour of the agents and interactions with other social networks in higher and lower levels (Giddens 1979; Malerba 2005). The interaction with foreign organisations and institutions, clients and a wider range of stakeholders would influence the behaviour and decision–making of agents in a specific sector. It is acknowledged therefore that the analysis of the behaviour of the bounded-network should not ignore the possible influence of the unobserved networks over the network under investigation. This is especially important in decentralised networks as the usual coherence provided by a leading organisation (a company or other form of association) is missing or tenuous.

In terms of ties, this framework limits its analysis to formal interactions occurring inside innovation projects. By focusing on innovation projects, the analysis emphasises tacit knowledge creation and flows rather than technology transfer by simple acquisition of equipment or traditional commercial transactions in direct acquisition of products and services (Bell & Pavitt 1993; Giuliani & Bell 2005). By delimiting the analysis to innovation projects, the analysis focuses on relatively dynamic capabilities, as projects are by definition characterised by their relative uniqueness and defined time span. To operationalise the elusive concept of *knowledge networks*, the economic transactions inside innovation projects are used as a proxy for the *knowledge flows* between multinational companies, domestic educational institutes and research institutes. Data on innovation projects is also used to break into the boundaries of the firm in different knowledge related activities examining the process of specialisation occurring in the arrangements between firms and technological partners and the longitudinal emergence of governance structures integrating knowledge in multinational companies and the host innovation system. Naturally, the economic flows in innovation projects are not equivalent

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[10] For some examples of individuals, groups, and industrial vertical and horizontal relations, see (Hobday 2000), (DeFillippi & Arthur 1998), (Acha & Cusmano 2005), (Manning 2005)

[11] Although these specific linkages, sometimes identified in the literature as 'university-industry linkages', have a considerable amount of literature of their own, they rarely allow the examination of the networks and governance structures formed by the aggregation of individual ties.

to knowledge flows. Nevertheless, following the flow of economic resources should provide us with an estimate of where the activity is. A finer distinction between these economic flows and the resulting directionality of the knowledge is further developed on the analysis of the underlying configurations in section 3.3.

Fourth, the knowledge base has been acknowledged as a fundamental contingency in the organisation of firms and the industrial structure (Foss & Klein 2008; Thompson 2003; Woodward 1980). This idea appeals to the evolutionary approaches, as it assumes that the technical requirements of different knowledge bases determine the structure of projects, organisations and networks and even paradigmatic changes in societies (Perez 2001). Acknowledging that organisational structures cannot be simply read from technical requirements, the recent literature on organisation of innovation has shown a renewed interest in recognising the knowledge base as a fundamental contingency in the organisation of networks(Birkinshaw, Nobel & Ridderstrale 2002; Tidd 2001). The reasons why the organisation of technological capabilities might differ from technology to technology remains a key topic of enquiry in the analysis of large firms and networks (Zander 1999a). Different technologies contain inherited characteristics that co-evolve with the structure of organisations and institutions.

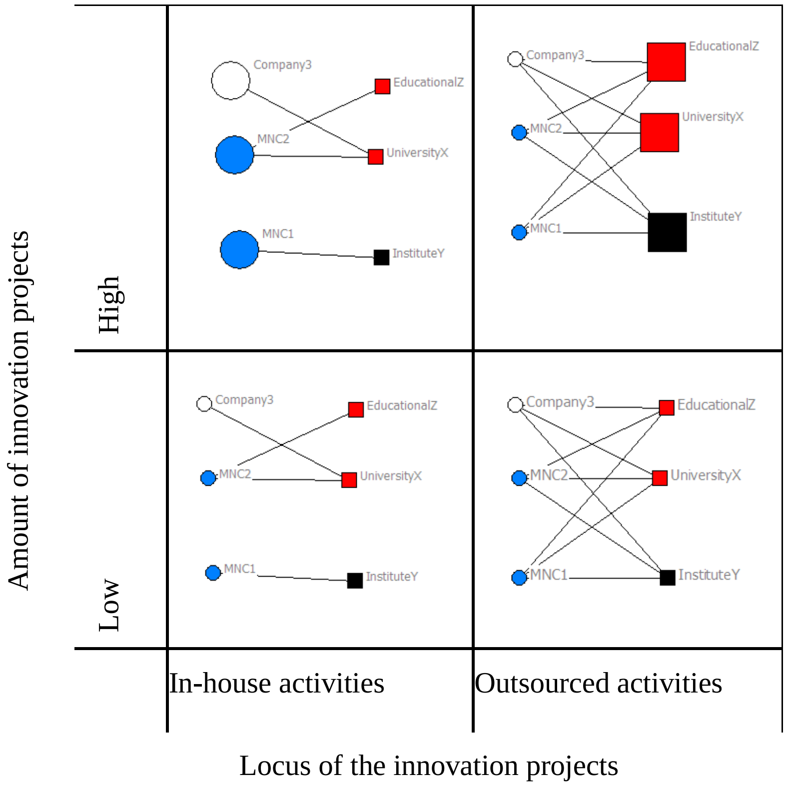
Following this initial definition of the knowledge network, specific structural aspects of the relationship between innovation projects and knowledge networks are developed inside this framework. In particular, the analysis focuses on the boundaries of the firm, the patterns of specialisation in the knowledge network and the stability and change in the inter-organisational linkages between multinational companies and organisations in the sectoral innovation system.

3.2.1. How do subsidiaries balance in-house R&D and external knowledge acquisition in different types of innovation projects?

The first question is related to how subsidiaries balance in-house R&D and external knowledge acquisition in different types of innovation projects. This raises important issues in relation to the nature of the interaction between multinational companies and sectoral innovation systems. The recent literature on innovation systems has started to examine the "multiplicity of networks" (von Tunzelmann et al. 2004). Although it is well-known that companies require input from external sources inside the innovation process (Tushman & Katz 1980), the ways and methods that the knowledge boundaries differ in different types of activities is still the focus of considerable interest.

The decision to perform in-house specific types of innovation projects or to use partners in their network fundamentally determines the characteristics of the emerging knowledge network (Gulati & Gargiulo 1999b). Figure 1 suggests a classification of knowledge networks formed between multinational companies and host country innovation systems. This classification is based on a distinction between the amount and locus of the innovation projects in the sector under analysis (Figure 3).

Figure 3 - Network Structure: Classification according to locus and size



Knowledge networks in the lower-left tend to represent firms conducting innovation projects with limited resources and where these limited resources are mainly allocated to in-house activities. In our framework, this would represent a very weak integration between the multinational firms and the host country educational and technological institutes. On the other extreme of Figure 1, this would tend to represent many large innovation projects where firms tend to substantially use (and depend upon) the technological and educational institutes in the host country. A deep integration between multinational companies and the host country innovation system is represented here. The other two corners represent intermediary levels of integration. The upper left quadrant would represent project networks built from projects with substantial size and high level of vertical integration. On the lower right, project networks with many horizontal linkages and limited total investments would be represented.

The key question however is to understand which factors explain the *amount of in-house R&D and external knowledge acquisition in sectors.* An investigation on the type of activities internalised and outsourced in innovation projects provides a necessary first step in the examination of the bottom-up evolution of the project-based knowledge network and its characteristics.

Two elements that would significantly influence the boundaries between in-house innovation and external acquisition of knowledge are particularly acknowledged here: the type of knowledge activity and the availability of external resources (i.e. disperse resources inside the knowledge network).

When considering how the type of knowledge influences the boundaries of the firm, a common "market-failure' explanation is that there is a division between public and private functions in the creation of knowledge. The rationale is that private companies tend to under invest in innovative activities when they cannot fully appropriate from their own investments. Companies would target investments at industrial R&D where they would be able to appropriate directly from their investments such as product and process development. The economic textbook could argue that companies would refrain from investing in some activities such as long-term research, training and other infrastructure.

Activities such as research, training and other infra-structure would have certain attributes of public goods[12], as several companies can make use of the published scientific results, the human resources in a region (through labour mobility), and public services, universities and research institutes. In these cases, the social benefits derived from these activities would provide a fundamental rationale for government intervention (Arrow 1962). The formation of public knowledge goods would allow individual companies to access the qualified human resources using the labour market and the network of services provided by different organisations such as universities and research institutes. Private firms would invest in these activities just to the extent necessary to allow them to absorb external knowledge. However, the recent literature has also recognised that there are increasing costs in product development. It follows that there are increasing gains to be made by the coordination and integration in capabilities among firms in a sector.

[12] Public goods are defined as goods with no significant diminishment of its value when used as input for production (non-rivalry) and that they cannot be prevented from use by other companies (non-excludability).

A complementary perspective is provided by the authors following a resource-based view of the firm. In the first moment, they would agree that organisations prefer to conduct product and process development projects internally as this knowledge becomes part of their competitive advantage (Teece 1988). A resource based view of the firm would argue that given the inappropriateness of market transactions in dealing with knowledge, firms will tend to vertically integrate their innovative activities in order to guarantee the appropriation of specific resources (Granstrand & Sjolander 1990; Patel & Pavitt 1998; Prahalad & Hamel 1990; Teece 1988). However, it is known that capabilities outside the firm would not be a substitute for internal capabilities (Brusoni, Prencipe & Pavitt 2001).

Increasing levels of coordination and integration among disperse resources are required to make use of technological opportunities in the competitive environment. Given the increasingly interactive nature of knowledge creation within sectors, the distinctions between public and private knowledge are increasingly fuzzy (Geuna, Salter & Steinmueller 2003). The innovation process is increasingly associated with overlapping capabilities between the capabilities of the integrator of knowledge and the external partners. This is particularly common in networks developing complex products and ICT technologies characterised by either uneven, relatively high rates of change within the underlying technologies or interdependency patterns that tend to change unpredictably (Brusoni, Prencipe & Pavitt 2001). The boundaries of the firm inside sectors are more complex than simple black and white distinctions between public and private knowledge (Nelson 1989).

Finally, following the work of Granovetter, many authors have argued for the overlapping informational structures related to the knowledge-creation in sectors (Granovetter 1973). Frequently, the literature distinguishes between distant and infrequent relationships (i.e., weak ties) and frequent and strong relationships (i.e. strong ties) using the Granovetter's original classification. For instance, examining the innovation process, Hansen has argued that weak ties are efficient for knowledge sharing because they provide access to novel information by bridging otherwise disconnected groups and individuals. Meanwhile, strong ties are likely to lead to redundant information because they tend to occur among a small group of actors with a common knowledge-base and a higher degree of shared-purpose (Hansen 1999)[13].

[13] Hansen expanded this analysis observing the 120 new-product development projects undertaken by 41 divisions in a large electronics company

From these complementary perspectives, it is possible to highlight that organisational boundaries would depend upon a balance between the varied overlaid networks that would have different structures in order to perform different functions. The nature of the knowledge and the availability of external resources seem to be crucial elements determining the formation of knowledge networks between multinational companies and host country innovation systems.

3.2.2. Which are the patterns of specialisation in the sectoral knowledge networks?

The link between knowledge and structure has a long tradition inside organisational studies. Some of the more traditional linkages are related to the contingency approach towards the examination of organisations. Contingency theory (Perrow 1971; Thompson 2003; Woodward 1980), would say that different types of knowledge should be associated with specific types of organisational structures. Different organisational forms develop specific advantages and disadvantages related to the internal co-evolution between technology, organisations and institutions. This line of thinking would support a certain functionalistic view of the sectoral system where different organisations are associated with specific roles through a technological determinism.

However, the contingency approach has encountered considerable criticism during recent decades. The recent literature on science and technology has constantly argued that social arrangements can never be read unproblematically out of technological requirements. A mix of organisational forms (models of governance) in otherwise similar networks could result in pronounced effects, not just on rates of innovation, but also on the process by which innovation takes place and on its content (Owen-Smith & Powell 2004). While in most instances, certain types of organisations would be connected with certain formal aims that would define them (e.g. universities, NGOs, private companies, research institutes). Individual actors in a sector may operate under a different set of strategic aims and under a different set of organisational principles.

Therefore, knowledge networks are not necessarily formed by relatively homogenous entities that are coordinated in a hierarchical manner. The underlying complexity of interactions would mean that individual organisations would pursue specific operative aims that are not necessarily aligned with wider formal sectoral aims proposed for the network[14] and heterogeneity would be a key characteristic of a complex sectoral network, resulting in a wider diversity of aims within individual organisations (Dosi, Winter & Nelson 2000; Malerba 2005).

In this context, an analysis of the process of specialisation in sectors is fundamental as it might unveil differences and complementarities between the roles played by different organisations. Characterising empirically how the knowledge base influences the division of labour within sectors is a relatively unexplored research question. The analysis of the types of innovation projects conducted by different organisations may provide relevant insights into their functions in the sector. Given the focus of this research, three groups of organisations are distinguished in this framework: subsidiaries of multinational companies, educational institutes and research institutes.

Subsidiaries of the Multinational Companies

In relation to the multinational companies, the literature describes many different roles of multinational companies when connecting to research institutes and educational institutes inside the sector (Gassmann & von Sedtwitz 1999; Ghoshal & Nohria 1989; Gupta & Govindarajan 1991; Kuemmerle 1999a; Paterson & Brock 2002; Schmid & Schurig 2003).

Here, the framework focus is on the distinction made by Kummerle. which distinguishes between two functions of the R&D labs in subsidiaries and the connections they will create within the host country. Home-base-augmenting R&D sites would tap into knowledge from foreign research endeavours, sending information from the foreign lab to the central or headquarters lab. Home-base-exploiting R&D sites would support foreign manufacturing or assist in adapting standard products to foreign demand, therefore, their information flows would be primarily from the central lab to the subsidiary lab.

Based on these premises, one could elaborate that home-base-augmenting R&D sites will develop their capabilities in areas where the host country has a recognised technological advantage. Home-base-exploiting R&D sites will not have these same demands, as they are mainly interested on the host-country market and/or inputs to production. With either focus, R&D will specialise their capabilities in core areas of the MNC network as they are absorbing these capabilities to develop their functions in the host country.

[14] This is supported by the idea that the normative definition of functions within the innovation in developing countries is usually relatively weak, as has been shown by many empirical qualitative studies, e.g. (Bell & Albu 1999)

Naturally, following the framework described in the beginning of this chapter, the role of different multinational companies should naturally be considered as a dynamic process. Understanding how subsidiaries specialise in a sector could, in principle, provide insights into the evolution of the capabilities in the multinational companies and the changing or non-changing nature of the multinational corporation (Zander 1998).

Division of innovative labour between MNCs and educational Institutes

The recent literature has been unanimous in its argument to increase the role of higher education institutions in the economic development strategy. The literature however is less coherent about the resulting question as to what this role should be.

Certainly, universities take central stage in knowledge production when this is measured by papers (Godin & Gingras 2000), and therefore their role is mainly connected to the creation of public knowledge. More recently, the ‘entrepreneurial university' is a phenomenon that points to the repositioning of universities in their capabilities and focuses on developing new products that could result in high-tech start-ups and clusters (Etzkowitz et al. 2000).

Authors examining university-industry links in catching-up countries have also observed a different role. Mathews argues that universities play a very special role in East Asia, but not as drivers of innovation as commonly viewed in the developed economies. He argues that they are key shapers of human capital formation (Mathews & Hu 2006).

In Latin America, the lack of university-industry linkages inside the innovation process has been the most common argument. Different authors suggest the need to strengthen mechanisms that would ensure learning between universities and industry in Latin America (Sutz 2000; Vedovello 1997; Velho 2004). Others argue that universities should play an important role in product development as well, particularly in the creation of small companies (Silva & Plonski 1999).

Although the focus of this research is not an in-depth examination of the university-industry linkages, investigating the functions performed by the higher education institutions in the interaction with multinational companies in developing countries is a relevant question that deserves empirical investigation.

Division of innovative labour between MNCs and technological institutes

The recent literature has highlighted the importance of research/technological institutes[15] as knowledge integrators and facilitators of the knowledge flow in regions and sectors (Sedaitis 2000). More recently, a particular link to the facilitation of the flow of knowledge related to multinational companies has been highlighted (Cooke & Morgan 2000).

In practice, however, the patterns of interaction between technological institutes and multinational companies have shown many cross-cultural differences. Some stylised profiling of public and private research institutes could highlight some of their different roles presented inside sectoral systems.

Public centres of excellence in specific areas are considered a source of dynamic comparative advantages in sectors and countries, fundamental to attracting high value added activities in an world with low trade barriers and increasing division of labour (Dunning 1998; Patel & Vega 1999). In developing countries, however, public research institutes are usually associated with the systemic transfer of foreign technology and subsequent adaption and diffusion to local companies. Authors like Kim and Mathews point out that public research institutes in East Asia played an important role in absorbing technologies from abroad which are needed by local firms and then diffusing these technologies in the local economy. In this process, they build capabilities in those technologies and subsequently transfer them to the private sector for economic exploitation (Kim, 2000; Mathews & Hu 2006). In the case of ICT industry in Latin America, Brazil was also the first among the countries in the Southern Hemisphere to establish a dedicated public research laboratory devoted to telecommunications technologies (Mani 2004; Mytelka 1996).

Private research institutes and other forms of association are also observed in the literature on innovation. For instance, as pointed out by Freeman, private research associations were established in the UK shortly after World War I; France, Germany and other countries followed soon afterwards. They became a means of sharing the costs of acquiring technical information and of technological services such as test facilities, product and process development (Freeman 1991).

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[15] Technological Institutes and Research Institutes are used interchangeably in this thesis

The role of intermediaries in the innovation process is increasingly acknowledged in the innovation literature (Howells 2006; Rush et al. 1995). Sapsed supported the argument that intermediary organisations may help unveil blocked opportunities in the boundaries of the sectoral innovation systems (Sapsed, Grantham & DeFillippi 2007). However, as discussed in this section, the patterns of interaction between the technological institutes and multinational companies remain an emerging area of research.

In contrast to a normative definition of the functions/technological areas of individual organisations inside the sector, different patterns should emerge mainly as result of interaction among actors that compete as well as collaborate in different forms. There are a number of empirical questions about the division of innovative labour between multinational companies, educational institutes and technological institutes that require empirical examination.

3.2.3. How fast do inter-organisational linkages emerge and change over time?

As discussed in section 2.2.1, opportunities for developing countries may emerge given the increasing integration of the global economy and the growth of knowledge networks in multinational companies. There is no obvious guarantee that this deeper integration will follow liberalisation of markets, although a first wave of small-scale projects may pave the way for larger-scale ones. The governance of innovative activities becomes increasingly diverse and complex in order to coordinate the knowledge flows between different public and private agents. The discussed literature argues that countries need to create institutions that would promote a deeper penetration of foreign direct investment (FDI) in R&D and speed up transformation of the host country system of innovation by exploiting new technological niches.

A knowledge network is the result of its unique historical experience and is developed in a unique path-dependent process (Gulati 1999). The longitudinal studies show that the knowledge of different partners from past experiences is fundamental to manage R&D activities. Experienced R&D units develop a greater number of non-R&D collaborations as well (Powell, Koput & Smith-Doerr 1996). This results in relevant implications for entrepreneurial behaviour as the structure of the network implies that firms are not equally situated to exploit profitable opportunities for cooperation. The development of an R&D network may take a long period of time.

The empirical research on networks assumes a certain persistence of network structure (Walker, Kogut & Shan 1997). Indeed, most of the organisational theory would point out that inertia, rather than plasticity, is the norm (Rumelt1995). However, the studies in innovation also show that stability will depend upon the context in which the network operates. In relatively stable environments, networks tend to be relatively stable as well. At the same time, networks also need to respond to changing characteristics of the environment and must evolve over time.

Technological dynamics is usually associated with significant organisational change in the structure of the knowledge networks. The analysis of secondary data on the US data communications industry shows that the emergence of new technical sub-fields results in shifting networks of strategic collaborations (Soh & Roberts 2003). The speed of change in the underlying knowledge networks in sectors may provide important insights about the dynamic of creative destruction/ technological accumulation in sectors.

The industrial product development networks are not only driven by exogenous factors such as the technology created in national universities and research institutes, but also by the endogenous differentiation of the capabilities accumulated by firms in the industrial structure (Gulati 1999; Gulati & Gargiulo 1999a; Nelson 1994). Balancing accumulation of internal capabilities and exploitation of external sources is at the centre of a firm's technological renewal and diversification.

In many sectors, such as ICT, the technological dynamism is associated with blurring boundaries of the form given the extensive need for inter-organisational collaborations (Antonelli, Geuna & Steinmueller 2000; Stuart 1998). Discontinuities in technological trajectories may result in important opportunities for new companies and may disrupt existing key players in sectoral networks (Christensen 1997).

Discontinuities in networks may also be the result of institutional disruptions. The transition to open economies requires an understanding of the reaction of the different actors within the system to the new set of incentives and how this impacts the accumulation of capabilities (Kim & Tunzelmann 1998; Radosevic 1999b; von Tunzelmann et al. 2004). However, our understanding about how multinational companies and local systems change and adjust to new conditions is still very limited.

The recent analysis of innovation systems in developing countries has put increasing emphasis on time and change and the need to understanding the rate of change both in terms of creation and transformation of these sectoral innovation systems (Bell 2006). However, it is still not clear how the speed by which the linkages inside the system respond to changes in institutional settings and technological opportunities. Examining the speed of change in the underlying knowledge networks can provide a way to examine the transformation in the sectoral systems given joint institutional and technological changes.

3.3. THE CONFIGURATIONS EMERGING FROM INNOVATION PROJECTS

On one hand, the literature on knowledge in multinational companies presented in section 2.2.2 suggests that creating and consolidating knowledge through projects is at the core of the recent analysis of the development of subsidiaries (and consequently, the evolution of multinational companies). On the other hand, as discussed in more detail in section 2.1.3, the network alignment approach highlights the multiple levels of governance involved in the alignment of innovation between global, national and local networks. In this context however there are still limited empirical studies at the project-level data which are trying to classify the different governance structures emerging from the interplay of the multinational companies and sectoral innovation systems.

Based on elements from organisation theory and the innovation system framework, this framework proposes that the underlying configurations in innovation projects in subsidiaries and their key technological partners is fundamental in explaining the evolution of the knowledge network. This framework suggests that this same principle of alignment used configurationally in approaches to the analysis of organisation could offer appealing complementarities with the concept of alignment as applied in the analysis of sectoral innovation systems in transition.

The concept of emerging configurations as discussed here has both similarties and differences with differing lines of conceptual development.

First, it is necessary to highlight that the approach developed in this framework clearly differs from some traditions in its examination of decision-making inside organizations. There is no attempt to identify a normative or prescriptive decision-making process inside the organizations such as in a descriptive approaches, that would, for instance, identify the best decision to taken, or assume the possibility or availability of fully informed decision makers. Bounded rationality is assumed as the underlying principle. Also, it does not delve into details on the issues related to principal-agent theory, and those related to asymmetric information nor to the differeces between the interests of the principal and agent As pointed out by Eisenhardt and Tabrizi, many organisational theories have their roots in the 1970s, a time when the concerns for speed and flexibility which now dominate contemporary firms were not an issue (Eisenhardt and Tabrizi 1995). Theories such as transaction cost economics are mostly static and therefore are not appropriate for capturing organisational forms in abruptly changing and competitive settings.

Second, from organisational theory, this framework borrows the concept of configuration from the organisational literature, defined here as a common pattern of alignment between organisation and strategy. This framework argues that the emerging configuration in innovation projects can be used as a central element for the analysis of the knowledge networks. Emerging configurations are proposed here as useful constructs to discuss the dynamic evolution of the knowledge network. According to the organisational literature, configurations emerge from the interplay among context, structure and strategies (Meyer, Tsui & Hinings 1993; Miller 1986). The configurational approach in organisational studies is an attempt to go beyond the idea of one variable at a time (usually associated with a contingency approach) towards a focus on the identification of some central themes that orchestrate the alignment among a great number of variables. This concept will be explored and defined in more detail in this section.

Third, there are similiarties in the approach suggested for this analysis and the structuralism theory (Giddens 1991). It is aligned with its basic assumptions that the macro perspective is more than simply the sum of all dyadic micro-level activities. While the social structures constrain the actions of individual agents, this same structure allows the possibility of reproduction of the structure through the repetition of the actions of individual agents. These structures are dynamic in nature, as they are neither inviolable nor permanent. Structure and action of agents constrain each other in an evolving way. As we explore the network, the structure of the knowledge network is influenced by the action of agents and this, in turn, limits the possibilites for the agents' performance.

Fourth, the concept of configuration used in this research has its similarities to the one of routine, used more in evolutionary theorizing (Nelson and Winter, 2002). Although there are many varations among authors depending on their own disciplinary approach and personal perspective, the concept of routine is deeply rooted in cognitive psychology as applied to organizations (Cyert & March, 1992). Cohen et al defined routine as "an executable capability for repeated performance in some context that has been learned by an organization in response to selective pressures (1996). By this definition, routine is one of the cornestones of the evolutionary thinking, encompassing all sorts of organizations and driven industrial complexity by the intentional and unintentional learning occurring in the economy. Feldman and Pentland suggest three possible ways to examine routines: (i) the entire routine as an undifferentiated "black box", (ii) the parts of the routines as "patterns of action" or (iii) the relationships between these parts and the processes by which they change. (2005). As pointed out by the authors, the exploration of the internal dynamics of routines opens up the possibility to examine how power dynamics operate and where conflicts exist and potential conflicts are likely to emerge.

Categorization and comparison of routines in different organizations, countries or through a period of time with a variety of methods is at the centre of the research on routines. Becker et al suggest the need for greater articulation of the methodology used to characterise them in order to promote greater comparability, in terms of its ontological level (2005). In most cases, the unpacking of routines has been limited to the organizational boundaries, or even subgroups inside the organizations (e.g. plants and productive units). The level of analysis explored here is related to the knowledge network formed by innovation projects (as already discussed in section 3.1. and 3.2), and is focused on patterns of action, and its changes over time. Given the nature of the innovation projects and the participation ofpeople from different organizations, the traditional organizational boundaries of the R&D department seem to be less relevant than the knowledge network itself. Those involved in the innovation projects as well as the governance mechanisms that guide its development seem more relevant in this context.

Thus, configurations, as described here, could be understood as a particular type of routine focusing on two particular aspects:

- The patterns of relationships between different stakeholders in terms of knowledge and financial flows
- The aims of different stakeholders in different configurations of innovation projects

This section not only develops a couple of exploratory questions but also discusses the different configurations in sustaining the knowledge networks formed by innovation projects which involve the subsidiaries of multinational companies in developing countries.

3.3.1. What are the common organisational configurations emerging in the network between multinational companies and innovation systems?

The review of the literature on the management of multinational companies (section 2.1) points to the increasing need to go beyond the theoretically driven typologies of subsidiary roles inside the multinational network, towards a dynamic understanding of the dynamic organisational development inside the subsidiary. In particular, learning and creation of knowledge in innovation projects are considered important elements in the evolution of knowledge in the multinational company. The identification of the patterns emerging from the innovation projects in subsidiaries of multinational companies and their main technological partners are acknowledged here as an important nexus between the analysis at the project-level and the governance in sectors. It is expected that the detailed examination of these patterns of intra- and inter-organisational linkages can provide insights into the direction and possible misalignments in the diffusion of knowledge.

A configurational perspective in organisational studies would departure from the principle that there is a limited number of recurring patterns in any organisational setting (or network, as is our level of analysis) (Meyer, Tsui & Hinings 1993). This congruence towards a set of patterns would occur based on the following evolutionary principles. First, the environment will select out combinations of structure and strategy that are not adequate to specific contexts. Second, only a limited number of configurations will result in relatively harmonic relations among their constituent parts. Third, organisations will tend to create new or change between discrete types of configurations relatively rapidly while these discrete configurations would tend to be reasonably stable over time (Miller 1987, 1996).

Therefore, understanding these sets of patterns would help us to simplify the organisational analysis to relatively less complex “building blocks” and, at the same, appreciate the complexity in the network formed by superimposed structures. This set of configurations should provide a basis to go beyond the examination of each one of the specific characteristics of the organisations that may provide sustainability to the networks in specific environments. In addition, by definition, configurations are assumed to have a reasonably stable nature and the identification of them in specific settings should provide us with a relative predictive power without excluding the role of agency.

Following these evolutionary organisational principles, this framework suggests that examination of the characteristics of the recurring configurations provides a basis to discuss institutional and organisational changes necessary to promote the sustainability of the decentralised knowledge networks and integrating agency and structure.

In principle, these sets of patterns could be defined from both a top-down manner (typologies), where possible configurations are developed based on conceptual frameworks (Birkinshaw & Morrison 1995), or derived from bottom-up empirical observations, resulting in taxonomies. The latter approach is used in this investigation. As previously discussed, the existing literature on the interrelation between multinational companies and local innovation systems both in international management and innovation studies tend to focus excessively on the first approach (i.e. based on theoretically driven typologies). Despite the relevant contributions of these typologies, this top-down method has endogenous limitations as it tends to ignore the interdependence between organisational variables departing from a conceptually defined typology (Meyer, Tsui & Hinings 1993).

The focus of this research is on developing bottom-up taxonomy of the possible configurations between structure and strategy in the organisation of innovative activities. Although this is restricted to specific historical and contextual circumstances, this taxonomy should provide a solid basis for expansion and validation in different contexts and sectoral settings.

Following the research questions, the current framework focuses on the configurations in the organisation of innovation projects between multinational companies and sectoral innovation systems. As discussed in section 2.1, different configurations inside the multinational company may emerge with strong internal intraorganisational ties but with miniscule presence of local partner participation and other functional areas of the subsidiary. This would voluntarily or involuntarily limit knowledge flows and knowledge spillovers. Other configurations focus on local aspects of adaptation and training, limiting absorbtion from more complex technologies.

Based on a configurational approach, rather than assuming the interaction among global and local partners, the trial and error in different innovative projects would result in the formation of configurations characterised by specific cognitive frames, business models and organisational structures that may 'systematise' the sectoral innovation system along its evolution. Individuals and organisations involved in innovation projects will learn through experimentation and under selective forces, to develop specific configurations. The existing intra- and inter-firm coordination linkages will influence the direction that the knowledge flows as it will also limit the scope in the subsequent search for opportunities; therefore, to characterise these bottom-up configurations in specific settings is crucial to the analysis.

3.3.2. How would different stakeholders benefit from knowledge and financial flows in different configurations?

In section 2.1.3, it was identified that the literature on innovation systems in developing countries has overemphasised a linear process of accumulation of capabilities through learning and has paid limited attention to the conflict of interests among different groups, particularly during the integration between global and local actors.

In the long term, organisations achieve advantages by constantly adapting the configuration of resources within a changing environment to meet the needs of markets and fulfil stakeholder expectations (Johnson & Scholes 1999). This is clearly connected with an evolutionary perspective on strategy, as this means "developing dynamic, path dependent models that allow for possibly random variation and selection within and among organisations”(Barnett & Burgelman 1996).

This framework assumes that specific configurations in innovative activities tend to satisfy the performance requirements of a limited number of stakeholders. Therefore, at the same time that they contain an inherited inertia and path-dependence, the discussion of individual configurations provides scope for agency and intervention inside the existing structure integrating domestic and multinational networks.

An analysis of different stakeholders involved in the innovation process recognises the need to understand how the characteristics of different interest-groups influence decision-making processes. The identification of the stakeholder can be used to investigate the behaviour, intentions, interrelations, agendas, interests, and the influence or resources that different actors have brought - or could bring - to the decision-making processes (Brugha & Varvasovszky 2000).

Configurations are assumed to have a reasonably stable nature as this corresponds to relative harmonic relationships among stakeholders. At the same time, the identification of the configurations in specific settings provides the map of those stakeholders that may promote change or benefit from the current status quo. Different stakeholders may also constrain the type of existing social networks established inside sectors, but innovation projects may lead different stakeholders to diverse experimentation.

At the same time that the widespread use of specific configuration probably reflects the identification of an economic opportunity in the sectoral innovation system[16], the path-dependence of the organisational arrangements may also present specific challenges as the kind of experimentation happening in the network could tend to be limited. Specific interest groups may block newcomers and create lock-in within suboptimal organisational arrangements.

The analysis of the aims of different actors in different configurations provides a way to address some of the constraints in the literature on project management that limits its analysis to specific project aims. Under an evolutionary perspective, the performance of an innovation project cannot be constrained to a simple criteria defined as ex-post monetary returns to an individual company (Juma 1986). It is necessary to assume that there are multiple possible outcomes for different types of projects and many of the externalities

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[16] It means, although some few may be experimenting under uncertainty, widespread use means consolidation and systemic exploitation of a model.

that result from the pursuit of R&D activities cannot be easily quantified nor are they understood in the short-run by the private agents involved.

Following from a stakeholder perspective, it is argued here that the existence of a configuration among a number of organisations is the result of a number of ‘successful projects through the lenses of the different stakeholders’. In other words, innovation projects could just be considered successful in the sense that they were able to *satisfy* the formal and informal criteria imposed by a number of stakeholders along the time. The simple existence of a configuration does not mean that it is beneficial for all the actors of a sectoral system. It simply means that its sustainability and repetition inside the network indicates that it is a desirable configuration for a specific number of actors.

Therefore,it is necessary to explore the variety of aims involved in organisations and knowledge networks and the evolving negotiation between subsidiaries and their key counterparts in the innovations system. Following evolutionary and organisational principles, this approach rejects ‘best-practices’ in terms of interventions in the sector as it needs to account for the existing configurations.

The explicit and implicit aims of different actors involved in different networks co-evolve with the patterns of intra and inter organisational linkages in the sector. The examination of the characteristics of the recurring configurations provides a basis to discuss institutional and organisational changes necessary to promote the alignment among actors in the decentralised knowledge networks (integrating agency and structure). An understanding of these linkages between the aims and the knowledge patterns in different configurations is fundamental if the implications of path-dependency in the sectoral knowledge network are to be explored.

The examination of the underlying aims of different groups of stakeholders involved in specific projects adds a key element to the analysis of interaction between national and multinational innovation systems. Given its focus on alignment in the knowledge network described in section 3.2, the key focus of intervention is the identification of ways to promote specific configurations that would compensate for specific unbalances in the network. Advancing the common good may require the development of proposals that satisfy the needs of each different stakeholder in technically feasible and politically acceptable ways (Bryson 2004). Understanding the underlying configurations is crucial to assess the scope for intervention.

3.4. SUMMARY AND CONSIDERATIONS

This chapter defines the framework for the investigation of the project based knowledge networks between multinational companies and sectoral innovation systems. First, it defines the three elements for the analysis of decentralised knowledge networks between multinational companies and host innovation systems: innovation projects, the knowledge networks, and the emerging configurations.

This framework focuses on the central role of subsidiaries in the link between multinational companies and sectoral innovations systems. The intra- and inter-organisational dynamics occurring around subsidiaries that focus on the key characteristics of the emerging configurations in innovation projects are focused upon a an approach compatible with evolutionary thinking.

This framework proposes a need to shift from theoretically driven typologies towards empirically based taxonomies of the organisational configurations emerging in sectors through the interaction between the knowledge base and institutions. The use of project-based knowledge networks as an integrative framework is an emerging area of exploration that may contribute to the economics, management and policy literature. The methods used for the operationalisation of the empirical analysis will be detailed in the next chapter.

4. METHODOLOGY

> *The structure of relations among actors and the location of individual actors in the network have important behavioral, perceptual, and attitudinal consequences both for the individual units and for the system as a whole. (Knoke and Kuklinski 1982)*

In chapter 3, a general framework was developed for the analysis of the decentralised project-based knowledge networks between multinational companies and sectoral innovation systems. This chapter presents the methods used to operationalize this general framework and analyse the empirical data.

The chapter is divided into four sections. The first part enunciates the key research questions orienting this research. The second section describes in more detail the research strategy and identifies the data sources used to explore the different dimensions of the theoretical framework. It is followed by a detailed explanation about the procedures used to analyse the data mapping the links to the theoretical framework. The last section provides a short summary and some considerations about the implemented research methods.

4.1. RESEARCH QUESTIONS

A core theoretical problem in network analysis is to explain the occurrence of different structures in the network level and, at the nodal level, to account for variation in linkages to other actors (Knoke & Kuklinski 1982). This general problem is applied to the innovation project-based linkages between multinational companies and sectoral innovation systems.

This research attempts to answer the following question: How does the organisation of innovation projects promote the sustainability of the knowledge networks between multinational companies and sectoral innovation systems?

The framework developed in chapter 3 is used to discuss structural characteristics of the knowledge network formed between MNCs and sectors in innovation projects and the role of the emerging configurations in innovation projects for the analysis of the organisation of key subsidiaries and their technological partners.

In relation to the characterisation of the knowledge network between multinational companies and key technological partners, three specific research questions are examined:

- **Organisational boundaries -** How do subsidiaries balance in-house R&D and external knowledge acquisition in different types of the innovation projects?
- **Functional differentiation -** Which are the patterns of specialisation in the sectoral knowledge networks (i.e. foreign and domestic companies, educational and technological institutes, public and private organisations)?
- **Stability and change -** How do inter-organisational linkages emerge and change over time?

In relation to the characterisation of the emerging configurations inside the knowledge network, two specific research questions are developed:

- **Patterns of intra- and inter-organisational linkages -** Which are the common organisational configurations emerging in the network between multinational companies and innovation systems?
- **The aims of organisations in different configurations -** How would different stakeholders benefit from knowledge and financial flows in different configurations?

The following section details the design of the research and data sources used to answer these questions.

4.2. RESEARCH DESIGN AND DATA SOURCES

As detailed in chapter 2, technological advances in ICTs, increasing internationalisation of R&D activities and the unanswered questions about the impact of FDI in developing countries show that there has been a substantial need to reconceptualise micro-macro relationships inside this complex setting between multinational companies and host innovation systems. This research aims to contribute to this large research stream by developing new methods to identify linkages between innovation projects and evolving networks between multinational companies and technological partners and then to apply them in an empirical case study.

As it will be detailed in this chapter, the network promoted by the sectoral policies inside the Brazilian ICT Law provide a natural experiment and a valuable source of data to investigate the configurations between institutions, multinational companies and the local innovation system in a developing country. An exploratory case study approach is considered the adequate strategy as, according to Yin, a case study is “an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident” (Yin 2003). In order to develop the case study, this research combines a number of quantitative and qualitative methods for investigating the case under analysis.

Combining quantitative and qualitative methods is an important feature of this research in networks. Although case studies tend to be associated with qualitative research, case studies can also use quantitative methods and provide a way to build theory (Darwin 2003; Eisenhardt 1989). A combination of qualitative and quantitative methods usually provides complementary strengths that should be explored (Flyvbjerg 2006). As pointed out by Van de Van and Poole, “qualitative data, by themselves, are like an amoeba, which while rich with life are squishy, soft, and absent of apparent structure. Only by combining quantitative and qualitative data in a balanced way do we come to understand the richness of life in its varied regularities”(Van de Ven & Poole 1990).

Table 2 shows the main quantitative and qualitative data sources in the different dimensions of the connection between project and network level (Chapter 3). The combination of quantitative and qualitative aspects provides complementary perspectives of the complexity and general patterns observed in the network under investigation and strengthen the proposals and conclusions emerging from this research.

Table 2 - Data Sources

Dimensions	**Quantitative data sources**	**Qualitative data sources**
Project level	SEPIN/MCT Database with details of 10.088 innovation projects executed under the Brazilian ICT Law between 1997 and 2003 (Annex 1 for details of the database structure)	Description of specific aims of key innovation projects (or group of innovation projects) (section 1 of the interview protocol – Annex 2). Validation with the detailed data on specific projects (reference to main projects in Annex 3), other secondary data collected and closed questions.
Organisational level	SEPIN/MCT database with 212 manufacturing firms of products under the incentives and 182 technological partners between 1997 and 2003, incluiding Project level data that could be aggregated to organisational level (Annex 1 for details of the database structure)	Detailed qualitative description about the nature of intra- and inter-organisational mechanisms (section 3 of the interview protocol – Annex 2) Validation with the agregated data on projects developed by the organisation (Annex 6), other secondary data collected and closed questions.
Network level	SEPIN/MCT database with network formed by more than 35000 transactions (payments inside innovation projects) between companies and technological partners declared under the ICT Law framework (This results in 948 ties between firms and technological partners considering the entire period)	Structured questionary describing the intensity of interaction with different actors (section 2 of the interview protocol) Validation with the position of the node in the sectoral network (Annex 5), secondary data and closed questions

This SEPIN/MCT database and the in-depth interviews with key multinational companies and their technological partners were the two main data sources of data to the analysis of the links between projects, organisations and networks in Brazilian ICT sector. These two data sources are detailed in this section.

4.2.1. The SEPIN/MCT database: Innovation projects declared under the Brazilian ICT Law – 1995-2003

Longitudinal quantitative analysis of the project-based knowledge network between multinational companies and educational and technological institutes inside innovation systems requires the construction and exploration of uncommon data. Large databases with details of innovation projects are rare for many practical reasons: there is an inherent complexity in gathering details of projects and participants involved in knowledge interactions among many organisations; these are usually conditioned to requirements of confidentiality; and, there are many difficulties in coding the different types of interactions in a normalised manner in order to construct representative databases. Empirical studies on innovation projects are usually hindered by these limitations.

Through a collaboration agreement with the Brazilian Ministry for Science and Technology, the database of projects used for administrative purposes was codified for this research. While adhering to the confidentiality requirements of the contract, this research uses the normalised administrative procedure for collecting data from the companies as the base for constructing the knowledge network conceptualised in section 3.2.

The Brazilian S&T Ministry was the main source since the individual projects were declared during the period of 1993-2003[17] in the Brazilian S&T Ministry (SEPIN/MCT). Three databases of the Brazilian Science and Technology Ministry were consolidated in order to produce the innovation network under study. The administrative procedure was particularly stable during in the period between 1997 and 2003 therefore most of the analysis focuses on this period in particular.

This consolidated dataset for the period between 1997 and 2003 contains 10.088 projects executed under the Brazilian ICT Law. The projects total a sum of R$ 1.6 billions executed internally by the companies and R$ 1.1 billions executed in partnership with universities and technological institutes. The projects declared correspond to the value of approximately 5% of turnover obtained from products under the tax break incentives. It means that companies may have had R&D projects not declared if they invested more than 5% in R&D/sales ratio (for most of the companies, the minimum ratio was progressively reduced in the last three years of the sample to 4.25% - i.e. - 0.25% points each year) . The dataset does not include the projects executed under the incentives of the Manaus region and other regional sources of incentives to innovation activities.[18]

Before entering into a discussion of the characteristics of these networks, it is useful to observe the relevance of the innovation projects database compared to the total investments in innovation in the Brazilian Telecommunications and Computers sector. One way to proceed is to compare the results with an external measurement of the total investments in R&D conducted by these two sectors. The total investments in R&D in the telecommunications sector and the computer sector by private companies as assessed by the PINTEC (Brazilian innovation survey) were R$627m in 2000 and R$637m in 2003 according to the two innovations surveys conducted in the Brazilian ICT sector (MCT, 2006). In addition, the innovation survey estimated that the total R&D outsourced to local

[17] 2003 was the last year for which the data was available and when the fieldwork was conducted. (July 2005)

[18] For more details on the legal framework that constitutes the ICT Law, see the SEPIN/MCT website (http://www.mct.gov.br/index.php/content/view/2189.html).

technological partners was R$153.9m in 2000 and R$184.2m in 2003. From these figures in this section, it is possible to estimate that the SEPIN database contains on average more than 55% of the investments in R&D in the computer and telecommunications sector (the average annual investments under the ICT Law were R$386m for the entire period) and more than 85% of the innovation projects outsourced to external partners in the sector[19].

Although there are some differences in the concept used to classify R&D in the two databases, the overall comparison would allow us to raise two important observations about the dataset: (i) The 212 companies in the dataset represent a significant proportion of the R&D in the sector. Most likely, other R&D activities are more disperse as the PINTEC database contains a much larger sample, such as software companies and services that do not have a manufacturing production system with products/minimum standards required by the regulations; (ii) a very significant part of the outsourced R&D in the computer and telecommunications sector in Brazil was indeed regulated by the ICT Law legal framework. Therefore, the ties identified in the knowledge network have provided an important estimate of the overall flows of resources inside the limits of the sector during the period under analysis.

Following the elements used for the analysis of sectoral innovation systems discussed in 3.2, it is useful to characterise the knowledge networks in terms of institutions, actors, knowledge base, and linkages. Table 3 shows some of the main characteristics of the knowledge network under investigation.

[19] It is supported by anecdotal information that highlights that outsourced R&D projects and the projects under the regulation are usually considered to be synonymous by the people interviewed.

Table 3 - The knowledge network under the Brazilian ICT Law

Dimensions	Description
Institutions	The Brazilian ICT Law – Manufacturing companies operating under the ICT were require to invest approximately 5% of the national sales in innovative activities (2.3% needed t involve a research and/or educational institute) in order to benefit from tax incentives. resulted in more than $2billion invested in innovation projects between 1997 and 200 (period under analysis)
Actors	212 manufacturing firms of products under the incentives (51 foreign companies and 16 domestic companies) 181 technological partners that met the regulation requirements (47 private researc institutes, 20 public research institutes, 75 private educational institutes and 40 publ educational institutes)
Knowledge	Innovation projects allowed under the incentives were classified using the followin categories: laboratory and infrastructure for S&T, quality systems for R&D, training in S&T technological services, development of products in hardware, software, semiconductor middleware, production process, as well as research activities.
Ties	948 ties between firms and technological partners. These ties were based on more tha 35000 transactions within innovation projects declared under the ICT Law framework.

In terms of institutions, the database is delimited to the network formed by innovation projects declared under the tax scheme developed in the Brazilian ICT sector, called ‘ICT Law’. The tax scheme defined R&D obligations proportional to sales in the national market in exchange for different types of tax exemptions/wavers for manufacturing companies’ products. In order to be entitled to the tax scheme the companies were obliged to invest approximately 5% of their sales in the national market in innovative activities[20]. Ex-post, the activities conducted would be described as structured project-type forms and in turn audited by the regulatory governmental agency (SEPIN) connected to the Brazilian Ministry of Science and Technology.

[20] This percentage decreased slightly during the last three years of the analysis. See www.mct.gov.br/sepin for more details about the regulatory framework.

In terms of actors, the dataset involves 212 companies and 181 educational and research institutes operating under the Brazilian ICT Law for the period 1997-2003. These actors are located throughout the entire Brazilian territory with the exception of the Manaus Free-Trade Zone, which receives specific incentives to manufacture and for R&D activities. The nodes of the network were companies and their 'technological partners'. The companies could be subdivided into national and multinational companies with local manufacturing of products operating under the incentives (usually products that integrate advanced electronics, such as computers, mobiles and telecommunication equipments). In turn, the technological partners could be subdivided into organisations that would fit the definition of educational and/or research institutes with either public or private ownership. The regulation defined that a specific part of the investments (approximately 40%) should be conducted with technological partners in an explicit attempt to promote university-industry linkages. These partners were especially important in the regulation that aimed to reinforce these organisations as the key nodes in the sector. The database of projects contains details on the costs of innovative activities both inside companies and with technological partners. As the regulations do not define the type of activities that should be conducted inside the firm boundaries or with partners, this database provides a useful source for investigating the firm decision-making to integrate vertically or use the network of partners to conduct specific types of activities.

In terms of ties, the knowledge flows are developed on the basis of more than 35,000 transactions within the projects between firms and educational/technological, creating 948 ties between these 392 nodes. These transactions are used to estimate and identify possible flow of knowledge among the organisations in the network. There were also transactions with other companies creating a wider, more open network (commercial software companies, suppliers of equipments and training abroad, and other organisations not classified as 'technological partners' inside the network). However the analysis of these transactions would add another layer of complexity and is therefore beyond the scope of this chapter.

This unique database of projects contains information from the executor of individual projects and transactions among firms and technological partners. These two elements facilitate the distinguishing of the organisations directly involved in the knowledge creation process and aid in the estimation of the process of inter-organisational knowledge flow. In terms of projects, the dataset contains 10,088 projects executed under the Brazilian ICT Law between 1997 and 2003 (an average of 1261 per year). The costs of the projects expanding beyond one specific year needed to be declared separately for the different years. The projects total an amount of R$ 1.6 billion executed internally by the companies and R$ 1.1 billion was executed in partnership with universities and technological institutes (annual average of R$ 358.1 million) (see table 4 for additional details).

Table 4- Longitudinal distribution of the projects

Total	1997	1998	1999	2000	2001	2002	2003	Average	Total
Investments ("R$)	304.3	346.8	389.5	560.4	249.6	349.4	306.3	358.1	2864.4
Number of projects	1194	1381	1439	1741	783	1235	1055	1261	10088
Average project size ('R$)	2421.5	2738.8	2907.5	3868.1	4555.0	4818.0	8799.7	3665.5	33774.1
Equiv. Staff/FT *	2637.2	2823.0	2666.2	3582.1	1535.3	2090.1	1563.6	2355.2	19252.6

* Estimated number of full-time staff (direct + indirect HR costs)/(Average Cost Man/Hour*2000)

The definition of the knowledge-base is connected to the definition used in the standard procedures, namely investments in laboratory and infrastructure for S&T, quality systems for R&D, training in S&T, technological services, the development of products in hardware, software, semiconductors, middleware[21], and production processes, as well as research activities. This categorisation at project level represents an advantage in terms of defining the knowledge base independently from the final product classification (.e.g. Pavitt taxonomy, most of the sectoral system studies) as it allows the existence of multi-technology firms (Granstrand & Sjolander 1990).

According to procedures declaring the projects inside the incentives, the responsible managers allocated each innovative project to the 11 categories. Projects also could be classified in more than one of the categories. (For example, a project could be allocated 30% in software, 10% in hardware, 20% in research and 40% in technological services). In this study, the resources allocated to 'others' were ignored.

In the original dataset, the companies were not classified according to the nationality of their ownership (i.e. domestic vs foreign). Considering that this is a key issue in this thesis, this additional variable was constructed based on data about ownership provided by Hoovers.

Annex 1 contains the map of variables available in the original dataset. Given the complexity of the database in terms of the number of variables and their interdependency, and the required work to clean and integrate different databases and tables, the examination of the knowledge network at the sectoral level focused mainly on the

[21] The original classification was 'System (hardware + software)' characterising projects in the interface. The term 'system' was substituted here for 'middleware' to avoid confusion with sectoral systems.

examination of the internal costs and economic transaction with technological partners. So far, limited attention has been given to examination of location-related characteristics and human resource aspects of the sectoral knowledge network. Also, there has been limited attention paid to the data related to the products and travel patterns. These variables were used however to enrich the 22 case studies and their internal organisation. Chapter 5 presents these characteristics of these knowledge networks in more detail including the geographical spread of the companies and visualisation of the network formed in different activities.

4.2.2. Selected multinational companies and technological partners

The investigation of the emerging configurations in the project based network was based on the comparative analysis of key characteristics of the key multinational companies and technological partners. The selection was based on investments in innovative activities among those companies and research institutes involved in the Brazilian tax scheme for promotion of innovation in manufacturing companies in the ICT sector ("ICT Law"). Table 5 shows the most important elements in the knowledge network divided by the type of activity. This table is useful to discuss the representativeness of the sample investigated in the field work. It shows 100 key nodes in the different networks. Interviews and detailed acquisition of secondary data were performed in the organisations shaded in grey. Given that many organisations interviewed were involved in different networks, the 11 MNCs and 11 technological partners interviewed are equivalent to 71 positions among these 100 positions.

Table 5 - Key players in the different networks (ranked by locus of implementation of the project)

Rank	Infrastructure	Type*	Quality	Type*	Technological Services	Type*	Training in S&T	Type*	Research	Type*
1	univap -	U	motorola i	MNC	~~cpdia - centro de p~~	~~PRI~~	1- eldorado	PRI	cpqd -	GRI
2	eldorado -	PRI	compaq com	MNC	informat - institut	PRI	informat – institute	PRI	~~cpdia -~~	~~PRI~~
3	northern t	MNC	bull tecno	MNC	brisa	PRI	ufpe – universidade	U	unicamp	U
4	lg electro	MNC	siemens lt	MNC	cpqd	GRI	~~alcatel te~~	~~MNC~~	fitec - fundação par	PRI
5	Ericsson t	MNC	nec do bra	MNC	solectron	MNC	~~nec do bra~~	~~MNC~~	informat - institut	PRI
6	cits - centro inter	PRI	microtec s	NC	iel-softpolis – ins	PRI	nokia do b	MNC	furukawa i	MNC
7	Flextronic	MNC(2T)	~~ibm brasil~~	~~MNC~~	itec s/a	NC	siemens lt	MNC	puc-pr - pontifícia	U
8	fitec	PRI	informat	PRI	lg electro	MNC	positivo i	NC	puc-rs - pontifícia	U
9	~~alcatel te~~	~~MNC~~	puc-pr	U	dell compu	MNC	lucent tec	MNC	cits - centro inter	PRI
10	~~cpdia -~~	~~PRI~~	ericsson t	PRI	ipem - instituto de	GRI	fcmf - fundação cas	U	cefet/pr - centro f	U

Rank	Production Process	Type	Hardware	Type	System	Type	Software		Semiconductors	Type
1	Compaq com	MNC	nec do bra	MNC	siemens lt	MNC	informat – institute	PRI	motorola i	MNC
2	pirelli ca	MNC	Motorola I	MNC	~~nec do bra~~	~~MNC~~	motorola i	MNC	itautec ph	JV
3	motorola i	MNC	itautec ph	JV	informat - institut	PRI	~~ibm brasil~~	~~MNC~~	instituto leonardo	PRI
4	solectron	MNC(2T)	siemens lt	MNC	fitec	PRI	hewlett pa	MNC	fdte - fundação par	PRI
5	bull tecno	MNC	cefet/pr	U	fmm –	PRI	northern t	MNC	unicamp	U
6	lg electro	MNC	solectron	MNC(2T)	ipt - instituto de	PRI	cits - centro inter	PRI	eldorado - institut	PRI
7	epson paul	MNC	lg electro	MNC	ericsson t	MNC	nec do bra	MNC	siemens lt	MNC
8	Celestica	MNC(2T)	fcmf	PRI	~~alcatel te~~	~~MNC~~	siemens lt	MNC	ipt - instituto de	PRI
9	Flextronic	MNC(2T)	cits - centro inter	PRI	~~ibm brasil~~	~~MNC~~	itautec ph	JV	autelcom c	NC
10	digicon s/	NC	ica teleco	NC	motorola i	MNC	finatel	PRI	cpqd	GRI

Organisations interviewed. **~~Xxxx~~ - No R&D lab in 2005.**

***(U)University (PRI) Private Research Institute (MNC) Multinational Company (MNC 2T) Second Tier Multinational Company (NC) National Company (JV) Joint Venture (GRI) Research Institute with part of its funding linked to the state.**

Source: Elaborated with data from MCT/SEPIN. Investments were allocated in the different categories according weights assigned to individual projects.

The 10 organisations with a strikethrough were not interviewed because they had no operating R&D units in September 2005. The remaining 19 organisations were excluded from the sample for being national companies or because access was not possible for logistic and budgetary constraints.

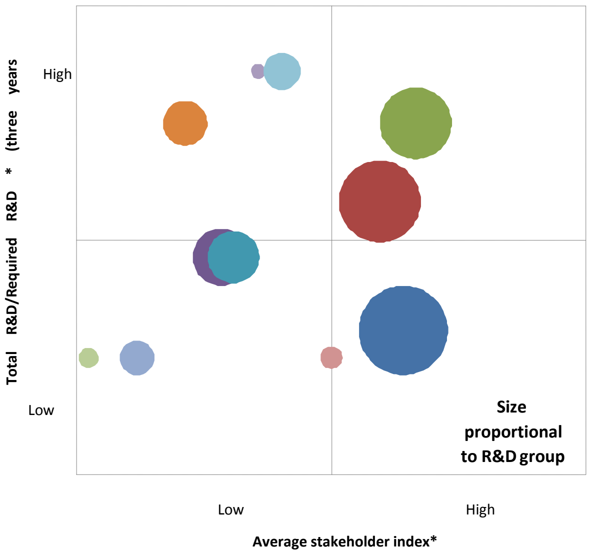
A few of the structured questions asked during the interview were used to characterise the sample. In order to explore the "sustainability of the emerging configurations", it seems important to consider how the activities in a specific organisation surpass the minimum requirements defined by regulation (in other words, whether a configuration would exist even if the regulatory framework did not exist) and how different organisations interact with a wider range of stakeholders.

Therefore two questions are used here to briefly characterise the different organisations that were the focus of the in-depth analysis. First, the percentage of the total R&D investments that surpass the minimum requirements defined by the sectoral policy and second, the strength of the interactions with a wide number of stakeholders. As the minimum R&D effort was regulated by legislation, an estimate of the total investments in innovation conducted in relation to the minimum investments required by the regulation in a particular year, provides a way to observe how individual companies geared the investments away from the basic requirement towards higher levels. In addition, the role of the subsidiaries in actively coordinating knowledge flows between stakeholders in the multinational company and different stakeholders in the industrial sector is considered. For the current need, based on data provided during in depth interviews, an attempt is made to measure the level of interaction of existing capabilities with disperse (and possibly conflicting) stakeholders in the sector.

Figure 4 plots the sample of subsidiaries in terms of the dependence on the tax scheme and the intensity of interaction with a wide number of stakeholders. The vertical axis represents the actual expenditure in 2005 as compared to the required expenditure in R&D (defined by the ICT Law). The horizontal axis is-based on an index composed of the average of the scores declared in question 3 of the questionnaire, where the intensity of the interaction with a large number of stakeholders was addressed.

The graphic illustrates the diversity of the selected subsidiaries in terms of the level of sustainability of their investments and the intensity of their interaction with a variety of stakeholders. This wide variety is desirable for the sake of theory development. The diversity of the cases enriches the investigation and possible analysis of different configurations inside networks.

Figure 4 – Sample of subsidiaries – Size of the R&D group, relevance of investments inside the ICT Law, diversity of stakeholders connected to the R&D group*

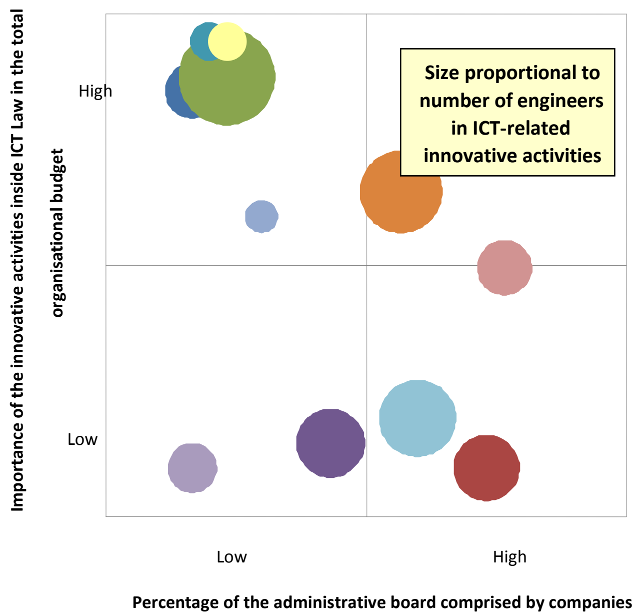


**Index based on the average interaction intensity index with a diversity of stakeholders*

Source: Structured questionnaire collected during the interviews

The same diversity is observed among their main technological partners. Figure 5 shows the importance of the innovation projects related to the regulatory framework, the total activities of different technological partners, the proportion of their board comprised by private companies, and the group size of R&D engineers working on ICT technologies.

Figure 5 - Sample of technological partners - size, relevance of the ICT Law and composition of the board



Source: Structured questionnaire collected during the interviews

The matrix shows a relative concentration on two extremes: (i) a number of organisations almost without participation of private companies in their administrative board and largely independent from the ICT Law legal framework (upper left); and (ii) organisations with a large number of seats allocated to private companies in the administration board (lower right) and with strong dependence on the resources from the ICT Law. It is important to notice that the first category does not necessarily mean public organisations, although most of the public organisations do tend to have less participation by private companies on their board.

A disclosure is required here. Although the different organisations were plotted here with relative precision, the location of these companies on the graphs above is just intended to provide an overall characterisation of the diversity, a scope of the cases explored and a measurement of the possible contribution of this research to theory development. No attempt to use these is suggested, or indeed, recommended given historical reasons for the location of the different organisations in specific positions.

Interviews were carried out with managers, especially seekingk out those directly responsible for the R&D investments (R&D functional and project managers). Additional interviews were collected in universities and research institutes that work in partnership with the multinational companies. The companies, as well as the names of some of their main innovation projects, are listed in Annex 3.

The names of the interviewed managers are listed in Annex 4. In total, 35 R&D managers participated in interviews that took an average of 90 minutes. The interviews were conducted between June and September 2005 in 5 different locations in Brazil (Porto Alegre, Curitiba, Sao Paulo, Campinas and nearby cities, Brasilia). The interview used a combination of structured and open questions. The size of the R&D laboratories ranged from 10 to 600 people.

The sample of subsidiaries conducted 2722 projects (internally and in partnership) between 1997 and 2003 (an annually average of 29 projects per subsidiary). The average innovation project size was around 500,000 reais (250,000 dollars) and some projects reached 50 million reais (~25 million dollars). The investments in innovation inside the ICT Law in this sample amount to $1.3billion reais (~650 million dollars for the period). The subsidiaries' average annual budgets were 15 million dollars.

Additional information was obtained during interviews. As well, information about the selected cases was collected and examined from other publicly available sources. Two non-academic conferences aimed at assessing the impact of the ICT Law in the sector were particularly important data sources. In these events, companies of different sizes and educational and technological institutes presented the capabilities developed though the innovation projects (MCT 2003, 2006).

Although the analysis of the project-based knowledge network is limited to the investments required under the regulatory framework and innovation projects declared,, in-depth interview with managers provided a way to discuss the micro-level differences. The in-depth interviews allowed the discussion of a wider range of organisational changes in the regulated companies that were pursued by different organisations in order to close the innovation loop and appropriate from the investments in innovation projects. Case studies are presented as boxes in chapter 7 describing the key configurations of the individual organisations.

4.3. ANALYSIS

The methods used for the analysis of each one of the research questions are discussed in this section. Table 6 shows the techniques and operationalisation of the dimensions following the framework developed in chapter 3.

Table 6 – Operationalisation of the variables and techniques for the analysis

	Dimensions	**Technique**	**Operationalisation of the variables**	**Results**
Project-based Network	Organisational boundaries	Trend Analysis, k-means and Anova test	In-house innovative activities in terms of total costs inside the different types of innovation projects Outsourced innovative activities in terms of total costs inside the different types of innovation projects	Section 6.1
	Functional differentiation	Revealed technology advantage (RTA) index	Amount of activities (in terms of total costs) according to the type of organisation (multinational company, national company, private research institute, public research institute, private educational institute, public educational institute)	Section 6.2
	Stability and change	The quadratic assignment procedure (QAP)	Correlation among the linkages formed between companies and research institutes over time and among different technologies	Section 6.3
Emerging configurations	Intra- and Inter organisational linkages	Cross case study comparison	Structured questions about intensity of interaction with different actors Detailed description about the characteristics of the intra- and inter-organisational mechanisms	Chapter 7
	Aims of different actors	Simplified stakeholder mapping	Details of main innovation projects conducted by the key organisations Detailed description about the advantages and challenges of different intra- and inter-organisational mechanisms	Chapter 7

The table also shows the location of the empirical results in chapters 6 and 7. Chapter 5 provides a descriptive analysis of the networks and key nodes and Chapter 8 applies the empirical results to discuss the links between the emerging configurations in innovation projects and the sustainability of the knowledge networks in the Brazilian ICT sector.

The variables and techniques used for the analysis are related to the key dimensions and research questions developed in the theoretical framework.

1. *Organisational Boundaries – How do organisations balance in-house R&D and external knowledge acquisition from technological partners in different types of activities?*

Based on the discussion presented in section 3.2.1, the amount of investments, the boundaries between firms and technological partners in innovation projects and the type of knowledge activity are proposed as a basis for classifying knowledge networks. In order to investigate these points, the relative amount of investments and boundaries between in-house and outsourced R&D activities are examined in ten different types of innovation activities throughout the allocated time period.

As described in section 4.2, managers classified individual projects among the following categories: infrastructure to R&D, technological services, training, hardware, middleware, software, semiconductors, process technology, other types of product development, and research. After visualising the different networks in Chapter 5, these different networks are analysed using the trend (two years average) for the investments in the different types of knowledge-related activites and within the locus of execution of the projects (firms or technological partners) in section 6.1. As the number of years is odd, 1997 is represented alone. The following years were paired (1998-1999, 2000-2001, 2002-2003), creating another three points.

A k-means procedure is used to initially cluster the knowledge networks in relation to their characteristics in terms of vertical integration of innovative activities and amount of resources in the network. Based on the structural differences presented by the different networks, a theoretical interpretation of the results was developed, and the significance of the differences between the vertical integration in different activities was verified using an ANOVA test.

2. *Functional specialisation - What are the patterns of specialisation in the sectoral knowledge networks (i.e. foreign and domestic companies, educational and technological institutes, public and private organisations)*?

In section 3.2.2, the role of different organisations such as foreign and domestic companies, educational and technological institutes, public and private organisations was discussed, coming to the conclusion that these organisations perform very different functions in different contexts and their specific specialisation in a sector remains an empirical question. Authors disagree particularly in relation to the different roles performed by these organisations in developing and developed economies.

In order to investigate this specialisation pattern, a specialisation index was adapted from the revealed technology advantage (RTA) index[22] (Patel & Pavitt 1994). In our case, we used the value of projects conducted by the organisation to arrive to the project-based revealed technological advantage (PRTA) index calculated for the different types of agents ("types of governance mechanism") for the different types of knowledge activities. The project-based specialisation index (PRTA) could be defined as:

[22] Index is usually used with patent and scientific publications.

$$PRTAij = \left(\frac{Pij}{\sum_i Pij} \right) \Big/ \left(\frac{\sum_j Pij}{\sum_{ij} Pij} \right)$$

Type of governance mechanisms (g) are divided among foreign companies, domestic companies, public and private research institutes, public and private educational institutes. Pij is the costs of said project executed by organisational type i in knowledge related activity j.

As in the traditional RTA, values greater than one suggest that an organisational type is comparatively specialised in the innovative activity in question relative to other organisational types (as it conducted more projects in this activity than the general average for the group), while values less than one are indicative of a position of comparative disadvantage. This procedure allows the control of the general concentration of specific organisations in a specific activity as well as for the institutional rules that define broader proportions that should be spent in companies and technological partners.

This procedure was repeated in two time periods (1997-2000) and (2001-2003) in order to examine how stable these characteristics were over time. The empirical analysis developed in section 6.2 permitted some numbers from the usual qualitative examination of the role of types of organisations in different settings to verify how stable these patterns are over time.

3. *Stability and Change in inter-organisational linkages - How fast do inter-organisational linkages change over time?*

In section 3.2.3, the speed of change in the knowledge network was discussed, pointing to the need of empirically investigating how the speed of change responds to institutional changes and technological opportunities. In order to investigate the speed of change in the knowledge network, a correlation analysis is used to investigate the interdependence between the structures of the along time and among different networks.

In specific, the Quadratic Assignment Procedure (QAP)[23] is used to investigate these changes. QAP is a method that has been used i n social network analysis, and is useful for analyzing dyadic data sets. It provides a measurement of the correlation between two networks. For instance, if for a given group, all the relationships of friendship are also business relationships, the result of the correlation will be 1. If for another group, friendship and business do not work hand in hand, the QAP procedure will tend towards 0.

[23] QAP correlation (# of Permutations: 5000,Random seed: 24322).

First, the QAP procedure is used for all the possible combinations of the ten knowledge networks (i.e. for each type of activity) in different years (between 1997 and 2003). This provides the degree of change in the network over time. Each network structure is represented by a valued matrix (A*ykk*), where y is the year and k is the number of organisations in the network. In this case, k is constant and equal to 391 as there are 212 firms and 180 technological partners in the network. The values of these networks are the sum of the transactions among partners (i.e. valued network). This procedure was also implemented based on a binary network.

The mathematical procedure could be defined as:

$$\text{Xii} = \begin{pmatrix} \text{Corr}(\text{A1kk}|\text{A1kk}) & \cdots & \text{Corr}(\text{A1kk}|\text{Aikk}) \\ \vdots & \ddots & \vdots \\ \text{Corr}(\text{Aikk}|\text{A1kk}) & \cdots & \text{Corr}(\text{Aikk}|\text{Aikk}) \end{pmatrix}$$

The result of the correlation is a matrix (Xkk) containing the strength of the overlap between each pair of networks.

Secondly, an additional Quadratic Assignment Procedure (QAP)[24] is used for investigating the relationship between the 10 different knowledge networks. This provides a cross-activity correlation. .In the case under analysis, the network structure in each one of the ten types of acitivities is represented by a valued matrix (A*ikk*), where it is the type of activity and k is the number of organisations in the network. Again, k is constant and equal to 398 as there are 212 firms and 180 technological partners in the network. This procedure is conducted for the entire network and additionally, just for multinational companies in order to identify if the general patterns of association differ between the two groups. The results of these analyses are presented in section 6.3.

4. *Underlying configurations in the knowledge network- What are the common patterns of organisation of innovation projects underlying the knowledge network?*

In section **Error! Reference source not found.**, the framework proposes that the empirical analysis of underlying patterns in the organisation of innovation projects is important to understand the evolution of the knowledge network. Different from the previous questions, the identification of these patterns is based on a mainly quantitative approach in order to allow for the complexity involved in the interaction between these two systems.

Using a structured diagram, interviewees were asked (i) to explain their main projects and internal groups inside the R&D department, (ii) to identify the intensity of the interaction

[24] QAP correlation (# of Permutations: 5000,Random seed: 24322)

of the specific R&D group in the subsidiary with 12 different possible groups of intra-firm, national or international stakeholders, and (iii) to describe the characteristics of the organisation in place related to the different types of innovation projects (see Annex 2 – section 2 and 3 respectively for details on the questions used in each one of these dimensions).

Given the time constraints in the interviews, a maximum of three different groups of innovation projects were selected to be discussed in detail. Whenever possible, key and unusual innovation projects inside the R&D department were discussed. Aswell, whenever possible, the answers in relation to the knowledge network (section 2 of the interview protocol) and organisational characteristics (section 3 of the interview protocol) were discriminated for each one of the projects (or project groups) in order to facilitate the comparison among cases.

Particular focus was given to the details of when, why and how different groups emerged, how these groups are sustained, and where specific activities are conducted. Whenever possible, the information provided during the interviews was crosschecked with interviews conducted with partners and detailed description of the projects. Secondary data on key innovation projects were identified, observing their organisational characteristics and inter-organisational linkages. Restraining the database of innovation projects analysed in the previous chapter to focus on a smaller number of multinational companies provided important complementary information about the dynamic in individual companies (Annex 6). Detailed description of the projects (for example, those mentioned in Annex 3) that formed a significant part of the innovative activities in the organisations researched were crosschecked with the information provided during the interviews.

This procedure allowed mapping usual knowledge and financial flows inside innovation projects. A taxonomy of configurations between subsidiaries and technological partners is suggested as a result of a reflexive balance between the idiosyncratic and general patterns that could allow the illustration of a representative percentage of the configurations in the specific organisational setting (Dess, Newport & Rasheed 1993; Eisenhardt 1989).

The cross comparison among different cases allowed the development of a taxonomy of usual configurations in innovation projects identifying usual stakeholders in each one of the configurations. The combination of qualitative and quantitative data on multiple case studies led to 12 different configurations in 11 key R&D labs of subsidiaries of multinational companies and their 11 main technological partners in the Brazilian ICT.

The different configurations in innovation projects were distinguished between those usually led by the multinational companies, those led by actors in the sectoral innovation system and those that involved a strong coordination between these internal and external networks.

Chapter 7 portrays this diversity among the subsidiaries and the technological partners investigated in more detail. The cases presented in the boxes in this chapter intend to exemplify both typical configurations and how these are superimposed.

5. *Aims of different actors - How would different stakeholders benefit from knowledge and financial flows in different configurations?*

As pointed out in section **Error! Reference source not found.**, rather than assuming that knowledge networks have their own aims, the analysis of the aims of different stakeholders in each one of the configurations emerging from innotation projects should allow us to suggest organisational strategies and policy interventions that could be promoted in a specific context.

The taxonomy of common configurations in innovation projects permit the identification of the common aims of different stakeholders and their general involvement in terms of knowledge and monetary flows. From the generalisation of usual knowledge and monetary flows in specific configurations, it is possible to map the stakeholders that benefit directly from the innovation activities performed inside specific configurations.

Following and simplifying procedures of stakeholder analysis (Brugha & Varvasovszky 2000; Bryson 2004; Frooman 1999), a table was constructed, highlighting those stakeholders that benefit from financial flows, knowledge flows or both. In this, the vested interest of generic stakeholders in each one of the configurations identified was made explicit. This map of aims in different configurations is presented in section 7.4.

This map portrays the advantages and disadvantages of specific configurations for relevant stakeholders. It also facilitates the analyses of how each one of the configurations in innovative activities is connected to specific needs of the sectoral system.

The previous questions provide the basis for answering the more general research questions of this thesis: *How does the underlying organisation of innovation projects promote the sustainability of the knowledge networks that are formed between multinational companies and sectoral innovation systems?*

In order to investigate the relationship between projects and knowledge networks, the characteristics of the project knowledge network observed in questions 1, 2 and 3 are linked to the nature of the inter-organisational linkages and aims in the underlying configurations examined in questions 4 and 5.

Elements of the general structure and the emerging network presented in chapter 6 and 7 should allow an in-depth examination of the implications to the specific sector under analysis. Chapter 8 contains an effort to design specific strategies and policies that acknowledges the characteristics of the existing knowledge networks between multinational companies and sectoral innovation systems. The sustainability of the knowledge networks promoted by the Brazilian ICT Law are discussed in each type of innovative activity (laboratory and infrastructure for S&T, quality systems for R&D, training in S&T, technological services, development of products in hardware, software, semiconductors, middleware, production process, as well as research activities).

In each case, strategies and interventions are discussed considering the usual configurations in the organisation of innovation projects that emerge in key actors. These strategies and interventions aim to reinforce or weaken specific characteristics of these networks and emerging configurations. As discussed in section 3.3, aspects such as investments in addition to regulated requirements and the increasing interaction between companies and technological partners are considered particularly important for the sectoral sustainability.

4.4. SUMMARY AND CONSIDERATIONS

This chapter described the key characteristics of the methods used in this research. Starting with the research questions, this chapter has explained the reasons for selecting the knowledge networks in the Brazilian ICT sector as a case, the strategies used to investigate the innovation project-based interactions between multinational companies and sectoral innovation systems and the data sources used to operationalise the elements of the theoretical framework. Finally, this chapter details the procedures used to collect and analyse the empirical data. The results of the empirical analysis are presented in the following four chapters. The linkages between theoretical and empirical chapters presented in this chapter are used in the final chapter to develop the key conclusions and theoretical implications of this thesis.

5. MAPPING OF THE KNOWLEDGE NETWORKS IN THE BRAZILIAN ICT SECTOR

"There are three kinds of death in this world. There's heart death, there's brain death, and there's being off the network."- *Almes, Guy*

This chapter introduces the general characteristics of the knowledge networks induced by tax schemes in the Brazilian ICT sector between 1997 and 2003. The 'ICT Law', as the tax regime is known, is one of the pioneering policies for the development of sectoral innovation systems in Latin America after the end of the import substitution policies. These incentives promoted an overall private investment of R$ 2.6 billion in innovation projects inside the Brazilian ICT manufacturing sector during the period under investigation involving 212 companies as well as 182 educational and research institutes.

After a brief overview of the institutional framework of the policies applied to the sector and recent studies assessing its impact, this chapter examines the most striking characteristics of the knowledge network formed by innovation projects inside the Brazilian ICT Law, particularly identifying the importance of multinational companies, the geographical spread of the network across different regions in Brazil and the different network structures emerging in different types of innovative activities.

The visualisation of these networks provides new empirical evidence to the polemic debate about the networks in the sector after the liberalisation, highlighting the evolutionary development of the capabilities of software in Brazil, the key roles of multinational companies and private research institutes, and the impact of the regionalisation policies on the intra- and inter-regional knowledge flows.

5.1. PERSPECTIVES ON INNOVATION IN THE BRAZILIAN ICT SECTOR– A BRIEF REVIEW

The policies regarding the ICT sector in Brazil started in the late 1960s and early 1970s as an effort to develop state companies to work on the Brazilian computer and telecom market (Hobday 1986; Worden 1997). Over decades, strict control on foreign ownership and the importation of equipment and components were imposed in the sector. However, given the increasing cost of the development of new technologies and the stifling impact that the backwardness in ICT had on the overall economy, the protectionist import substitution model ultimately collapsed during the early 1990s.

The studies in the Brazilian ICT sector show that, at the end of this period, the Brazilian ICT sector was characterised by a large backwardness in software, some capabilities in hardware and microelectronics in national firms, and considerable capabilities in telecommunication systems, mainly developed around public research institutes such as the CPqD (originally the research centre of Embratel – the state telecom company) responsible for most of the technology development in telecom during the import substitution phase (Mytelka 1996).

Similar to the other reforms that took place in Latin America in the 1990s, the liberalisation was influenced by assumptions that the liberalisation of the market and the inflow of FDI would mean: (i) *a natural source of information and technology for local companies* - an open market, especially in high-tech industries, would be directly related to a greater diffusion of knowledge, therefore, leading inevitably to a catching-up process. Endogenous firms would benefit from competition and thrive in the globalised market; (ii) *a reinforcement of existing centres of excellence in research* - private companies were expected to promote higher investment in R&D, while the state would focus on investments in different elements of the system such as universities and research institutes; (iii) *a strengthening of existing clustering activities* – based on the experiences in the US and Europe, the government was keen to copy the experiences that supported entrepreneurship through non-firm organisations, such as technological parks and incubators. This trend would be reinforced by changes in the multinational strategy towards a decentralised production of knowledge and has resulted in the remergence of an optimistic outlook related to possible 'knowledge spillovers'.

However, fifteen years later, the results are quite mixed. The liberalisation process, which involved one of the largest privatisation programmes in the world, undoubtedly has yielded benefits to the modernisation of the infra-structure in Brazil. End-users who struggled in long waiting-lists for expensive fixed and mobile lines enjoy the benefits of competition in the sector (Tigre et al 2001). However, the recent studies conducted in the sector point to the impact that the process has had on indigenous capabilities.

In relation to telecommunications, recent evidence points to the considerable disruption in the previous cluster in Campinas organised around the CPqD (Schjolden 1999; Szapiro & Cassiolato 2003). The institute was privatised, although an important part of its sustainability remains connected to federal funding. In terms of its core technological capabilities as the previous centre of technological development of the indigenous cluster, the institute was reoriented towards other activities such as consulting and technological services (Mani 2004). The dynamic of the sector shifted towards a dynamic centred on multinational equipment suppliers. However, the patent and publications indicators point to a very low presence or importance of Brazilian subsidiaries in the creation of knowledge inside the multinational companies, although some of them are integrated into global product development networks (Galina & Plonski 2002).

Software emerged as one of the most promising sectors in Brazil. However, despite some examples, most national software firms are still fragmented in dispersed, small companies that lack the characteristics to reach the international market. (Arora & Gambardella 2004b; Arora, Gambardella & Torrisi 2004; Tigre et al 2003). In 1993, the government initiated an official network of institutes, technological partners and incubators in order to support entrepreneurship and the integration of the industry with the external market, called SOFTEX, based on the experiences in the US. However, according to a detailed analysis provided by Stefanuto, the Brazilian Software Export agency (SOFTEX) was never capable of materialising the developmental goal proposed. Despite the lack of investments during its initial decade, it remained the governmental official policy in relation to the Software Policy (Stefanuto 2004a).

In the face of these recent studies, the drive for the accumulation of technological capabilities in the ICT industry in Brazil remains unclear. Common to the study of the software and telecommunications sector mentioned above, is the observation that the tax scheme, called the 'ICT Law', is one of the most important aspects in defining the current situation of the sector. However, the similarities in their opinions about the incentives stop there.

The studies, even in the same sector, disagree largely on the impact, varying from highly beneficial to the creation of capabilities, to the formation of total subservience of the sectoral dynamics to transnational interests. For instance, Tigre et al argued that a substantial part of this R&D investment is simply customisation or adaptation of imported designs to local needs and other activites oriented to individual users' needs and is usually based on standard hardware and software platforms(Tigre et al 2001). In contrast, Cassiolato, Guimarães and Lastres argued that the idea of fostering R&D expenditures has proved to be a naïve attempt and has shown poor results (Cassiolato, Guimarães & Lastres 2006).

Recently, some studies have tried to provide a more direct evaluation of the impact of the policy in the sector (Campos & Teixeira 2004; Garcia 2002). Their analyses point to the fact that the incentives did not promote the accumulation expected. However, the authors also agree that their analysis is insufficient, and there is a need to better understand the specific organisational development and the accumulation of capabilities inside the scope of the industrial policy.

However, the existing structure and dynamic of this network is not clear for its members and society. This chapter intends to provide an additional empirical contribution to this debate on the (i) concentration of the resources, (ii) the role of different actors in different technologies, (iii) and the process of geographical distribution of the sectoral knowledge networks. Although there are some limitations in the inductive approach adopted here, this exercise aims to demonstrate general trends on how the institutional policy co-evolves with the organisations and technological opportunities in the sector. This will provide the basis to test specific questions about the organisation of the knowledge network in the next chapter.

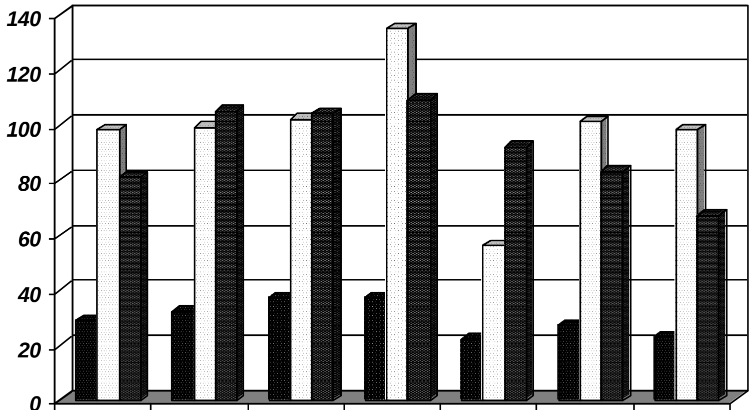
5.2. CHANGES IN THE INSTITUTIONAL FRAMEWORK

In most of the relevant variables to this research, the legal framework defined by the Brazilian ICT Law could beconsidered relatively stable during the period under analysis. There were however some changes in the institutional framework that substantially impacted the organisation of the knowledge network. Particularly important here are the increasing requirements for technological partners and the geographical requirements for the investments defined in 2000 and implemented mostly in 2001.

5.2.1. Increasing requirements for technological partners

One of the important changes implemented in 2000 was an increasing regulation of the institutional requirements for being qualified as technological partners. This significantly reduced the number of organisations participating in the knowledge network as shown in figure 6.

Figure 6 – Number of organisations under the incentives of the ICT Law between 1997 and 2003

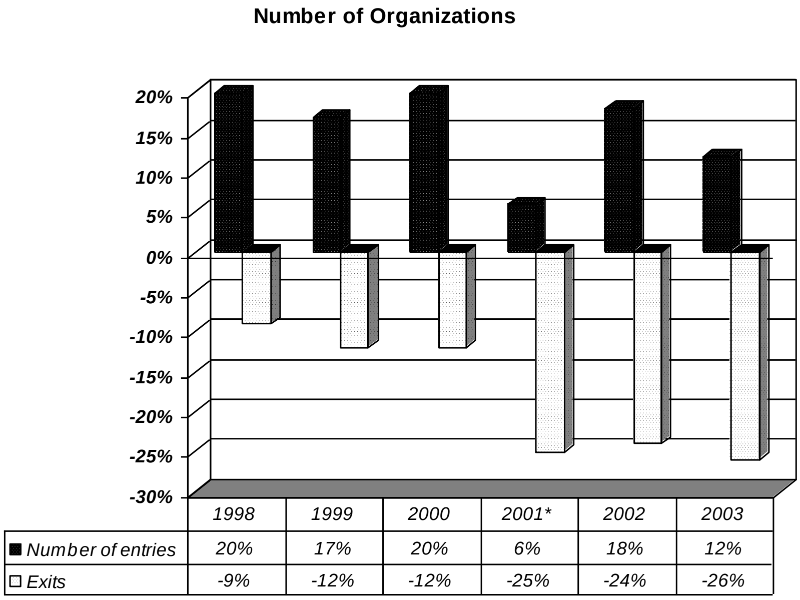


	1997	1998	1999	2000	2001*	2002	2003
Foreign companies	29	32	37	37	22	27	23
National companies	98	99	102	135	56	101	98
Technological Partners	81	105	104	109	92	83	67

There were a relatively high number of technological partners exiting the regulatory framework in the last period as a result of stricter regulation. In 2000, there were more than 109 technological partners, but this was reduced to 67 by the end of the period. The graph shows that there were also some delays in the implementation of the new law in 2001 resulting in certain discontinuity in the legal framework impacting positively, then negatively, the number of foreign and national companies that declared projects in the year 2001. In general, however, under the regulation, the number of national companies involved ranged between 98 and 102 organisations and the foreign firms between 23 and 37 organisations.

The overall number of entries and exits in the knowledge network is shown in figure 7. Giving the lack of available data, this analysis does not account for acquisitions, fusions or possible changes in names of different companies.

Figure 7 – Exits and Entries in the Knowledge Network



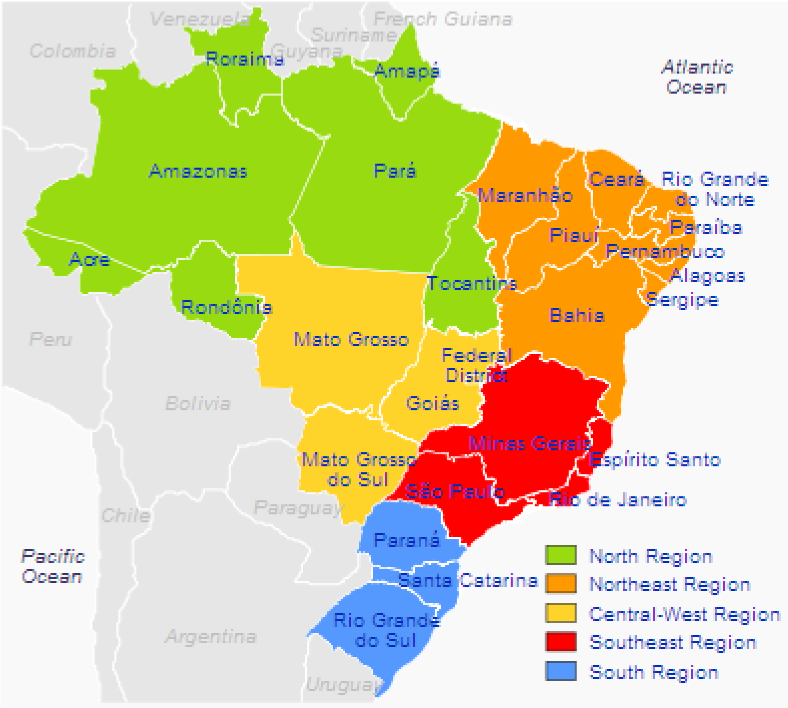
These numbers show there is a considerable volatility in the number of companies between the different years ranging from 6% and 20% in the number of entries and between 9% and 26% in the number of exits each year. These numbers are particularly high in the last period, mainly because of the reducing number of technological partners (as previously discussed).

Another important reason for turbulence in the technological partners that were involved in the knowledge network is related to the location of the incentives, as described in the next section.

5.2.2. Geographical distribution of the knowledge network

Important regional differentiations were included in the legislation in order to promote a decentralisation of the investments. Until 2000, the legal framework did not differentiate companies and technological partners according to regions. The Brazilian ICT Law was initially applied in an indiscriminate way to companies and educational and research institutes all over the Brazilian territory with the only exception being the Manaus Free-Trade Zone – capital of the Amazonas state (figure 8), which receives specific incentives for manufacturing and for R&D activities and is not represented in this analysis. During this initial period, companies were able to select partners independent of location.

Figure 8 – Map of Brazil - States and regions



Specific changes in the legislation were introduced in 2000 in an attempt to decentralise capabilities throughout different regions and companies were required to contribute to a sectoral fund and include partners in economically less developed regions among their investments (Central West, North and Northeast) following the specific rule presented in Table 7.

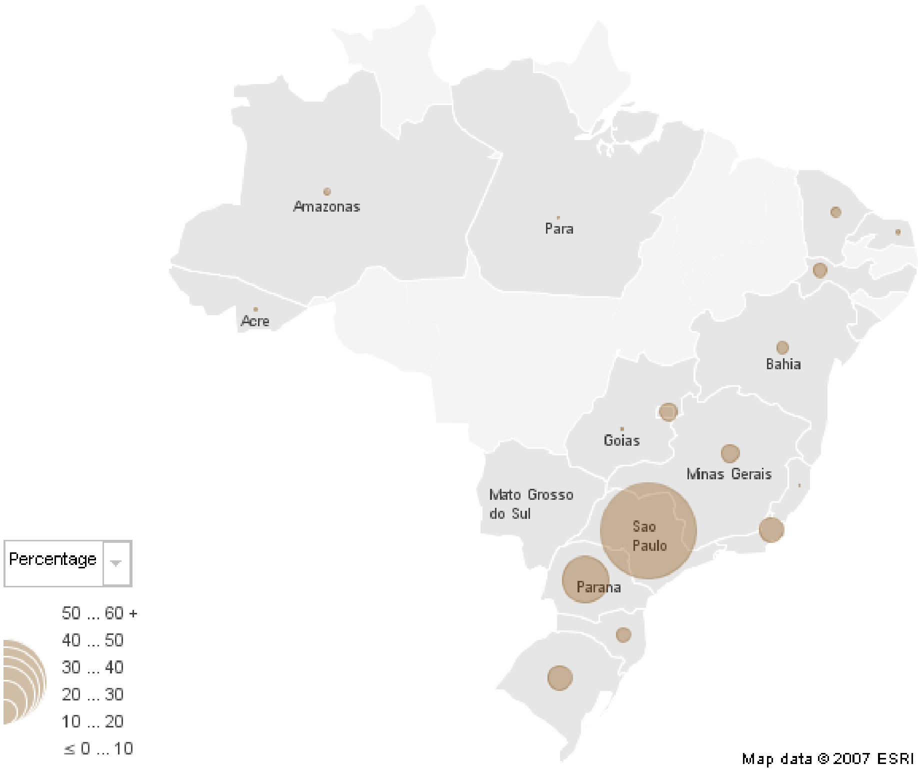
Table 7 – The ICT Law No. 8.248/1991, amended by Law No. 10.176/2001 - General rule of reductions of incentives and the IPI rates for investments in R & D of the benefiting companies. (Between 1993 and 2004)

Year	Investment in R & D							
	TOTAL	**Internal**	**External**					
		Made by the company itself and they hired	**Total**	**Agreements with accredited institutions, contracting of projects with companies linked to accredited hatcheries and the Priority Programs**				**Sectoral fund - CTInfo**
				Any Country Region	**Midwestern, Northern and North region**			**Deposits**
					Total	**Nature of Entities**		
						Public or Private	**Public**	
Company based in the regions Midwestern, Northern and North region								
1993-1999	5,00%	2,700%	2,300%	-	-	-	-	-
2000	5,00%	2,700%	2,300%	1,000%	0,800%	0,5600%	0,2400%	0,500%
2001	5,00%	2,700%	2,300%	1,000%	0,800%	0,5600%	0,2400%	0,500%
2002	4,85%	2,619%	2,231%	0,970%	0,776%	0,5432%	0,2328%	0,485%
2003	4,60%	2,484%	2,116%	0,920%	0,736%	0,5152%	0,2208%	0,460%
2004	4,35%	2,349%	2,001%	0,870%	0,696%	0,4872%	0,2088%	0,435%
Companies based in the South and Southeast								
1993-1999	5,00%	2,700%	2,300%	-	-	-	-	-
2000	5,00%	2,700%	2,300%	1,000%	0,800%	0,5600%	0,2400%	0,500%
2001	4,75%	2,565%	2,185%	0,950%	0,760%	0,5320%	0,2280%	0,475%
2002	4,50%	2,430%	2,070%	0,900%	0,720%	0,5040%	0,2160%	0,450%
2003	4,25%	2,295%	1,955%	0,850%	0,680%	0,4760%	0,2040%	0,425%
2004	4,00%	2,160%	1,840%	0,800%	0,640%	0,4480%	0,1920%	0,400%

Source: Adapted from MCT (2003)

Figure 9 shows the geographical distribution of the investments for the period between1997-2003 according to the state of the executing institution. More than 60% of the investments were concentrated in the Sao Paulo state, followed by investments in Parana and Rio de Janeiro.

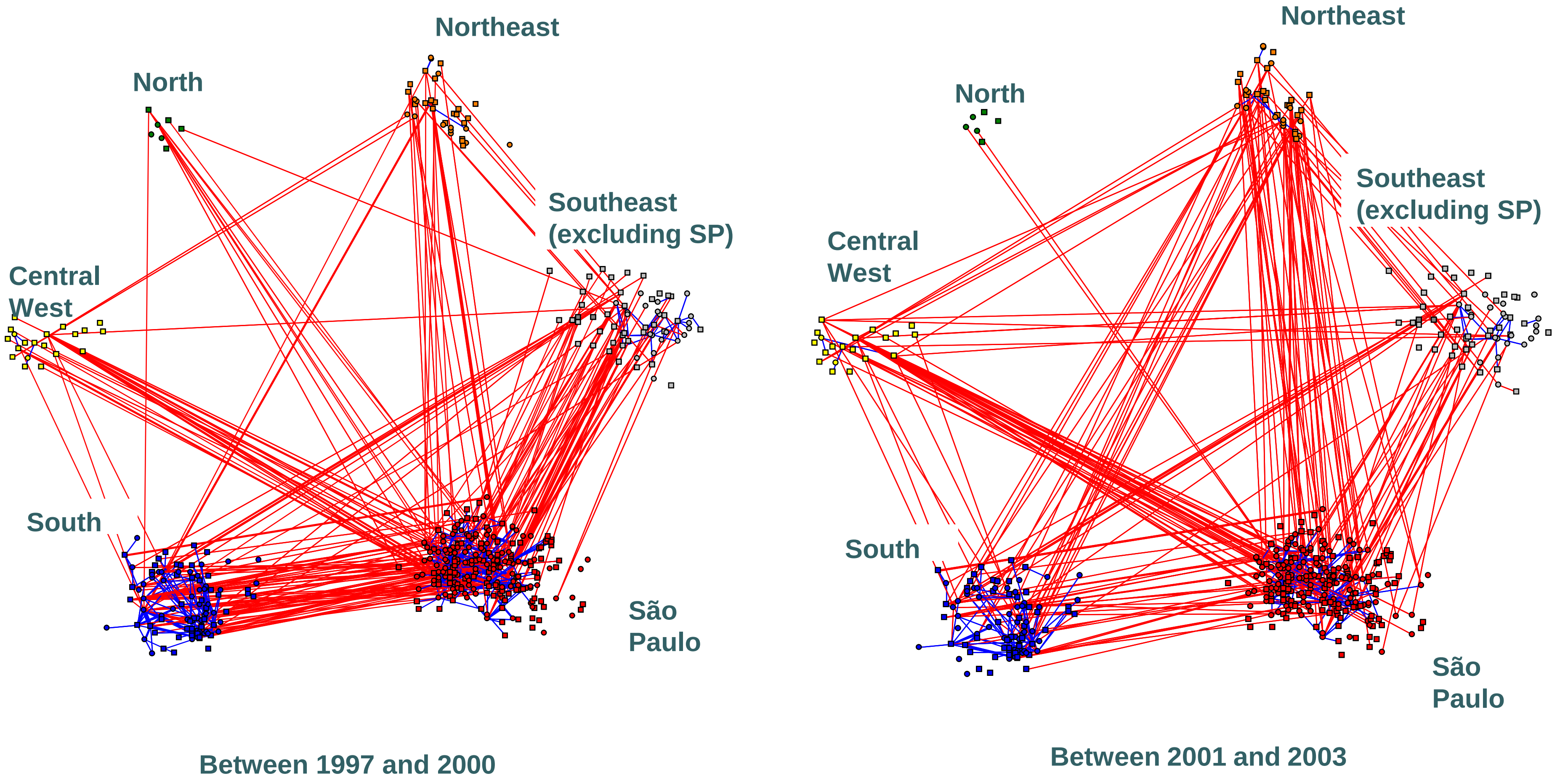
Figure 9 - Investments in innovative activities declared under the Brazilian ICT Law by State of the executing organisation (1997-2003)



A more detailed visual examination of the intra- and inter-regional patterns of collaborations in two different periods (figure 10) shows some different patterns emerging from the introduction of the regionalisation rule. The nodes of the network are companies and their 'technological partners' are divided according to one of the five regions in the Brazilian territory. Given the very high concentration in São Paulo, the state was considered a region in its own, allowing the investigation of its internal dynamic and the relationship with the other states in the South East region (Minas Gerais, Rio de Janeiro and Espírito Santo).

The first graph shows that during the first period, there was a strong agglomeration in Sao Paulo, and strong inter-regional linkages with the South and Southeast region. The comparison with the second graph seems to indicate that the number of inter-regional linkages increased with states in the Northeast and Central East, as expected by the policy intervention. It seems however though that the number of linkages with the southern regions decreased over time.

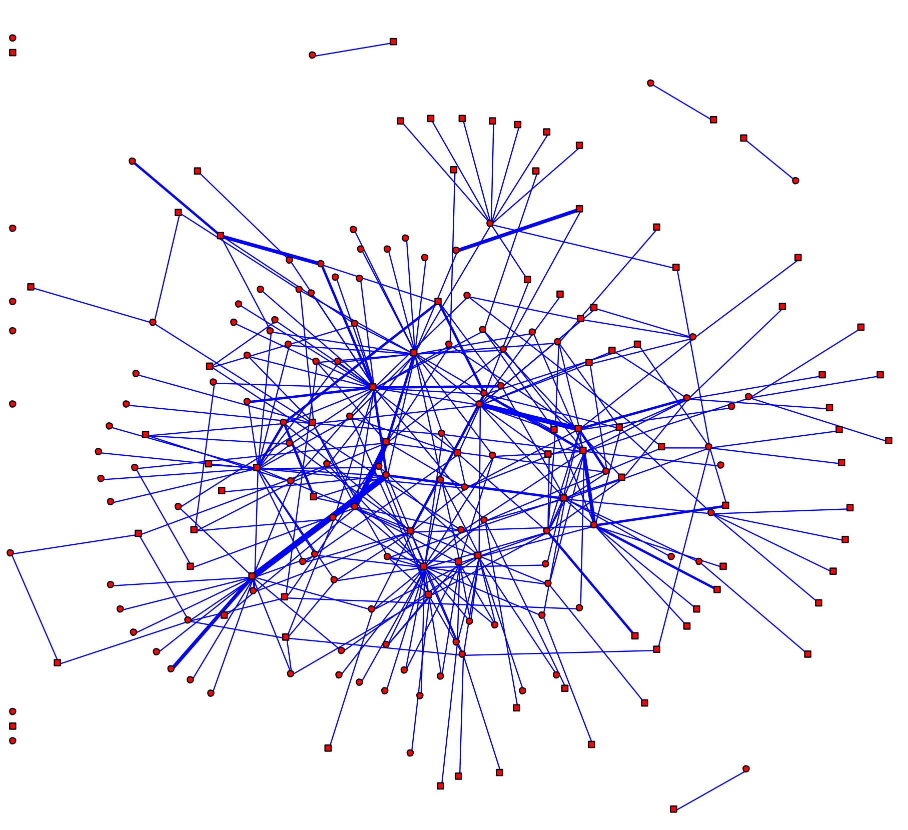
Figure 10 – Inter-region networks in Brazilian ICT Sector divided in two periods

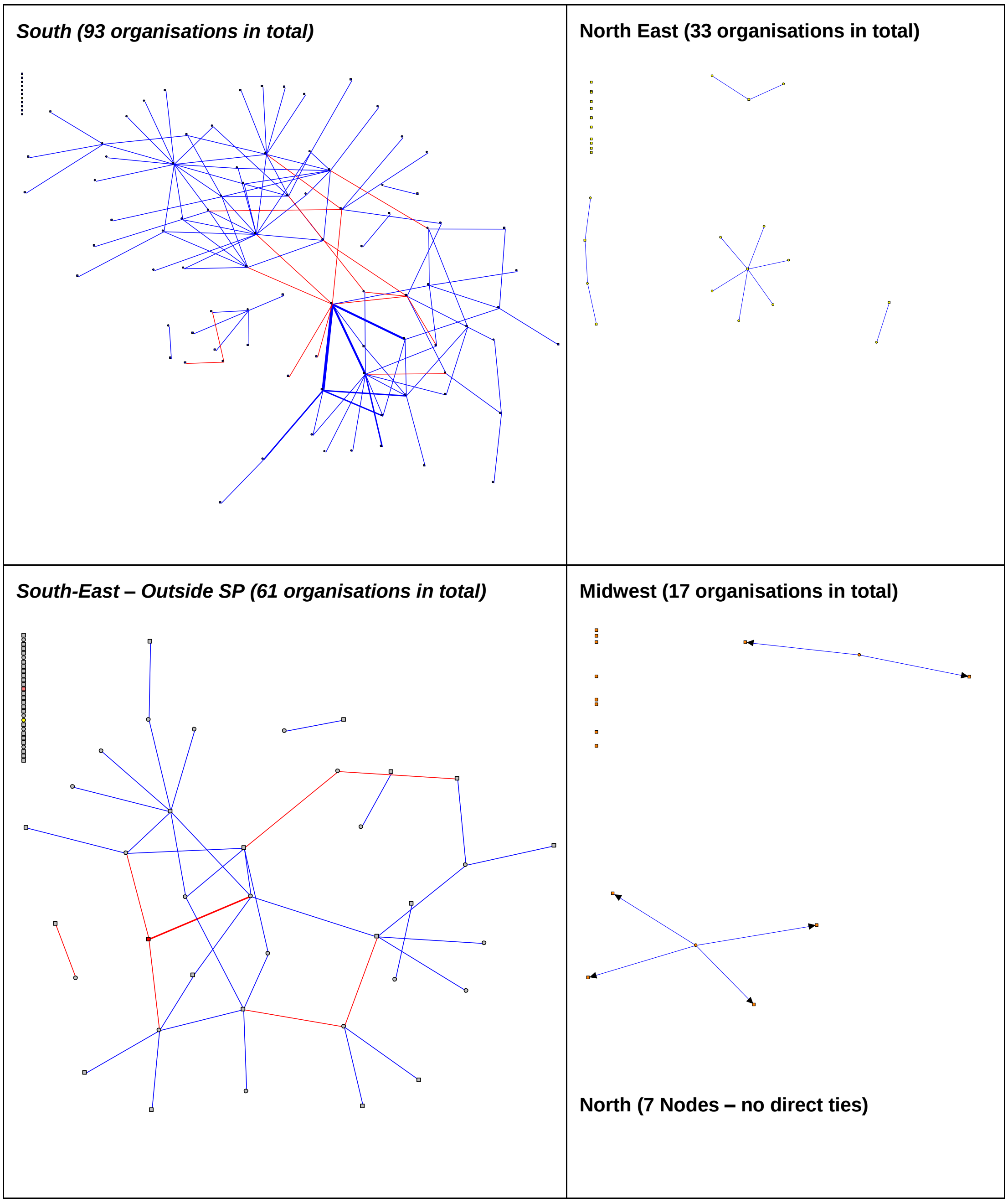


A closer observation of the structure of the intra-regional linkages is provided by figure 11. The graphs show that indeed Sao Paulo is the geographical location that does contain a strong intra-regional dynamic, followed by some dynamism in the South and South-East. Intra-regional linkages are clearly less important for companies and technological partners in the Central-West and Northeast region.

Figure 11 - Intra-regional knowledge linkages

Sao Paulo (226 organisations in total)





The visual analysis of these networks demonstrate that the intra-regional linkages among organizations in Sao Paulo is quite developed (a rather dense network is show in the diagram), linkages among organizations in the North and Midwest are rare (there are just 12 linkages amon the 33 organizations in the Northeast and just 6 linkages among the 17 organizations in Midwest). The South region and the South-East (excluding Sao Paulo) are in an intermediary position.

The intra- and inter organisational dynamics could also be discussed in more quantitative terms using the inward and outward payments in collaboration with innovative activities across regions in terms of the sum of total payments (Table 8) and the absolute count of collaboration (Table 9).

Table 8 - Intra- and Inter-organisational linkages - Inward and Outward collaboration in innovative activities in different regions (Percentage of total investments in innovative activities outsourced to technological partners)

				Inward Region						
				South	Sao Paulo	Southeast (exc. SP)	Central West	North	Northeast	Total
Outward Region	South	Table Sum %		13.0%	1.1%	.4%	.8%	.0%	1.2%	16.5%
		1997-2000	Table Sum %	15.3%	1.5%	.7%	.1%	.0%	.2%	17.7%
		2001-2003	Table Sum %	9.5%	.6%	.0%	1.9%	.	2.7%	14.8%
	Sao Paulo	Table Sum %		4.4%	62.6%	3.8%	3.5%	.1%	4.3%	78.8%
		1997-2000	Table Sum %	5.2%	67.3%	2.5%	2.4%	.1%	.9%	78.4%
		2001-2003	Table Sum %	3.2%	55.5%	5.8%	5.1%	.1%	9.7%	79.4%
	Southeast (exc. SP)	Table Sum %		.0%	1.0%	.8%	.3%	.6%	.2%	2.8%
		1997-2000	Table Sum %	.0%	1.2%	.8%	.3%	.0%	.0%	2.4%
		2001-2003	Table Sum %	.0%	.7%	.6%	.3%	1.5%	.4%	3.5%
	Central West	Table Sum %		.	.0%	.	.6%	.	.0%	.6%
		1997-2000	Table Sum %	.	.	.	.7%	.	.	.7%
		2001-2003	Table Sum %	.	.0%	.	.5%	.	.0%	.5%
	North	Table Sum %		.	.1%	.	.	.	.	.1%
		1997-2000	Table Sum %	.	.1%	.	.	.	.	.1%
		2001-2003	Table Sum %	.	.1%	.	.	.	.	.1%
	Northeast	Table Sum %		.0%	.4%	.1%	.1%	.	.5%	1.2%
		1997-2000	Table Sum %	.	.0%	.0%	.0%	.	.7%	.8%
		2001-2003	Table Sum %	.0%	1.0%	.2%	.2%	.	.2%	1.8%
Total	Table Sum %			17.4%	65.3%	5.1%	5.3%	.7%	6.2%	100.0%
	1997-2000	Table Sum %		20.5%	70.1%	4.1%	3.6%	.1%	1.7%	100.0%
	2001-2003	Table Sum %		12.8%	57.9%	6.7%	7.9%	1.7%	13.0%	100.0%

Table 9 - Intra- and Inter-organisational linkages - Inward and Outward collaboration in innovative activities in different regions. (Percentage of total number of partnerships)

			Inward Region						
			South	Sao Paulo	Southeast (exc. SP)	Central West	North	Northeast	Total
Outward Region	South	Table Valid N %	12.9%	3.8%	1.2%	1.9%	.1%	2.8%	22.7%
		1997-2000	16.3%	4.5%	1.6%	.5%	.2%	.3%	23.4%
		2001-2003	12.9%	2.4%	.4%	2.8%	.	5.0%	23.5%
	Sao Paulo	Table Valid N %	6.9%	36.2%	5.5%	7.5%	.9%	7.4%	64.4%
		1997-2000	8.9%	44.6%	6.6%	3.1%	1.0%	2.3%	66.6%
		2001-2003	5.4%	30.7%	4.2%	10.4%	.4%	11.8%	63.1%
	Southeast (exc. SP)	Table Valid N %	.3%	1.2%	3.8%	.7%	.2%	1.1%	7.3%
		1997-2000	.3%	1.6%	4.7%	.2%	.2%	.3%	7.3%
		2001-2003	.2%	1.0%	2.2%	1.0%	.2%	1.6%	6.2%
	Central West	Table Valid N %		.1%		.7%		.1%	.9%
		1997-2000		.		.7%		.	.7%
		2001-2003		.2%		.4%		.2%	.8%
	North	Table Valid N %		.4%					.4%
		1997-2000		.3%					.3%
		2001-2003		.4%					.4%
	Northeast	Table Valid N %	.2%	1.0%	1.0%	.8%		1.3%	4.3%
		1997-2000	.	.2%	.5%	.3%		.5%	1.6%
		2001-2003	.4%	1.6%	1.2%	1.0%		1.8%	6.0%
Total	Table Valid N %		20.3%	42.8%	11.5%	11.5%	1.2%	12.7%	100.0%
	1997-2000	Table Valid N %	25.5%	51.2%	13.5%	4.9%	1.4%	3.5%	100.0%
	2001-2003	Table Valid N %	18.9%	36.3%	8.0%	15.7%	.6%	20.5%	100.0%

The tables reflect the importance of the São Paulo region, source of 78.8% of the resources invested in technological partners and 64.4% of the collaboration agreements between companies and partners inside the ICT Law. This is followed by the South and the other states in the Southeast. A very small part of the collaboration agreements were originated from companies in the North[25] (0.1%), Northeast (1.2%) and Central East (0.6%). Despite some small variations, the spread of investments in technological partners by outward region remained reasonably stable over the two periods.

The analysis of the inward resources of partners according to regions however, shows that there was a deep change in the allocation of resources among technological institutes in different regions. In Sao Paulo, there was a decrease in the concentration of investments from 70% to 58%;. The other states in the Southeast were able to sustain and indeed increase their participation (from 4.1% to 6.7%); however there was a large proportional decrease in investments in institutes in the South with a sharp fall from 21% to 13% of the total resources. Meanwhile, institutes in the Central-West and Northeast strongly increased their participation: institutes in the northeast increased from just 1.7% to 13% and in the Central East, from 3.6% to 7.9%.

These tables also demonstrates that while intra-regional collaboration agreements were indeed very important in São Paulo, inter-regional arrangements were a limited part of the action in other regions. For instance, in the Central-West and Northeast, almost all the resources originate from firms in southern states. This resulted in limited local linkages in these regions.

As pointed out in the theoretical framework (section 3.1), the core of the analyis in this research is related to a sectoral innovation system approach, and although the geographical dimension is relevant, it is not at the core of the research questions examined in this research. At the same time, the brief introduction to the geographic distribution of the network presented in this section is important to understand the overall dynamics of the institutional setting and the spread of the sector in Brazil. It also demonstrates the importance of the location of the subsidiaries and technological partners interviewed during the field work, mainly concentrated in Sao Paulo, followed by the Southern region and the other states of the Southeast.

5.3. VISUALISATION OF THE KNOWLEDGE NETWORKS AND KEY NODES IN DIFFERENT ACTIVITIES

This section focuses on the analysis of the networks formed during innovation projects between companies and technological partners declared under the Brazilian ICT Law. This chapter draws on detailed and rich data on innovation projects to examine some basic characteristics of the knowledge network emerging from the application of incentives to

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25 Again, there were specific incentives to manufacturing in Manaus that are not included in this database.

innovation in the Brazilian ICT sector. Following the procedures detailed in section 4.2.1, the innovation projects were used to examine ten different knowledge networks in the ICT sector according to the type of activities: laboratory and equipment infrastructure, technological training, technological services, R&D quality systems, process technology, product development in software, middleware, hardware and semiconductors as well as research activities.

The examination of the knowledge network was based on the construction of a relational database of secondary information on the innovation projects under the Brazilian ICT Law between 1997 and 2003. In order to allow the visualisation of the knowledge network in different activities, the general network was 'sliced' according to different types of activities (as discussed in section 4.2.1).

In order to visually explore the dynamic in different types of activities, knowledge networks between companies and their technological partners are presented based on innovation projects in different activities. In each case, companies are represented as circles and technological partners as squares. Domestic companies are represented in white, foreign companies are represented in blue, educational institutes are in red and research institutes in black. The diameter is proportional to the sum of innovation projects conducted by the specific organisation during the period between 1997 and 2003.

The value of R$1 million in collaborative activities was selected as an arbitrary number to define "large collaborations" and as a way to permit the visualisation of the key structures inside the dense network.

Table 10 summarises some basic statistics about the network in terms of investments in projects and according to the type of activities. The table also contains some details about the density and concentration in the different networks.

Table 10 - Descriptive Statistics about the 'ICT Law' Knowledge Network - 1997-2003

Dimension	Infrastructure	Quality	Technological Services	Training in S&T	Semiconductors	Production Process	Hardware	System	Software	Research
Sum of Investments (" R$)	169.7	118.2	84.7	159.5	44.7	108.9	203.4	621.7	838.3	121
(with partners)	103.7	27	65.8	100.4	4	13.5	46.3	212.4	385	97.2
Number of firms	142	170	104	177	30	140	191	234	271	195
(with partners)	64	67	76	87	15	44	81	127	157	111
Number of Partners	96	52	71	117	18	54	71	92	140	121
Number of Ties	174	120	162	240	22	90	141	230	425	304
(>R$ 1M)	18	5	12	20	1	3	8	31	56	23
Tie strength (' R$) Average	570	174	387	388	189	145	304	799	830	309
Tie strength (' R$) Maximum	11584	3349	20957	28565	1427	1818	7300	28188	58622	9229
Concentration – (10-Firm Ratio)	73%	53%	72%	70%	99%	63%	63%	64%	70%	65%
Concentration -(5-Firm Ratio)	42%	36%	51%	51%	97%	47%	48%	49%	45%	48%
Concentration – (3-Firm Ratio)	26%	26%	40%	41%	95%	38%	34%	36%	29%	37%
Concentration – (1-Firm Ratio)	9%	10%	25%	25%	72%	23%	13%	16%	12%	18%

Source: Own elaboration based on MCT/SEPIN data

The total investments internal within companies and with partners in each one of the type of activities differed considerably. While in semiconductors, just R$ 48.7 million was invested in innovative projects, the investments in software sum up more than R$1.2 billion during the period (R$838.3 internal to companies and R$385 million in partnership).

This is also reflected in the general number of partners, number of ties created, and strength of the ties. Both in software and system innovation projects, there were approximately 800 ties, and in software, more than 56 of these ties were valued at more than $R 1 million in outsourced activities to partners.

In proportional terms, however, other activities tended to have a disproportioned number of ties. When considering number of ties in relation to the total investments, there were just 1 tie/R$ million in Infrastructure and laboratories projects, 1.6 ties/ R$ million in training projects and the index rise to 2.1 for technological services and 2.5 for research activities. These numbers contrast significantly with averages of 0.4 to 0.6 ties/ million reais invested in the other ‘product development’ networks.

Another important characteristic of the knowledge networks which is shown in the descriptive statistics is related to the concentration of the investments. The 10-firm ratio shows that in most activities, 10 companies were responsible for more than 60% of the total investments (with the exception of Quality) in each of the networks presented in Figure 1.

The different ratios show that most of the networks followed a very similar pattern of concentration, with the exception of semiconductors, where the investments were extremely concentrated (72% originated from one company). One company usually had between 9% to 25% of the investments in specific technology; three companies represented between 26% and 41%; and 5 companies approached half of the investments in the specific technology. Clearly, these patterns of concentration are very high, reinforcing the relevance of examining the key players in order to understand the dynamic of each one of the networks.

The following sub-sections detail the analysis of each one of these networks and its key players in order to provide an in-depth characterisation of the dynamic in different types of innovative activities.

5.3.1. Research

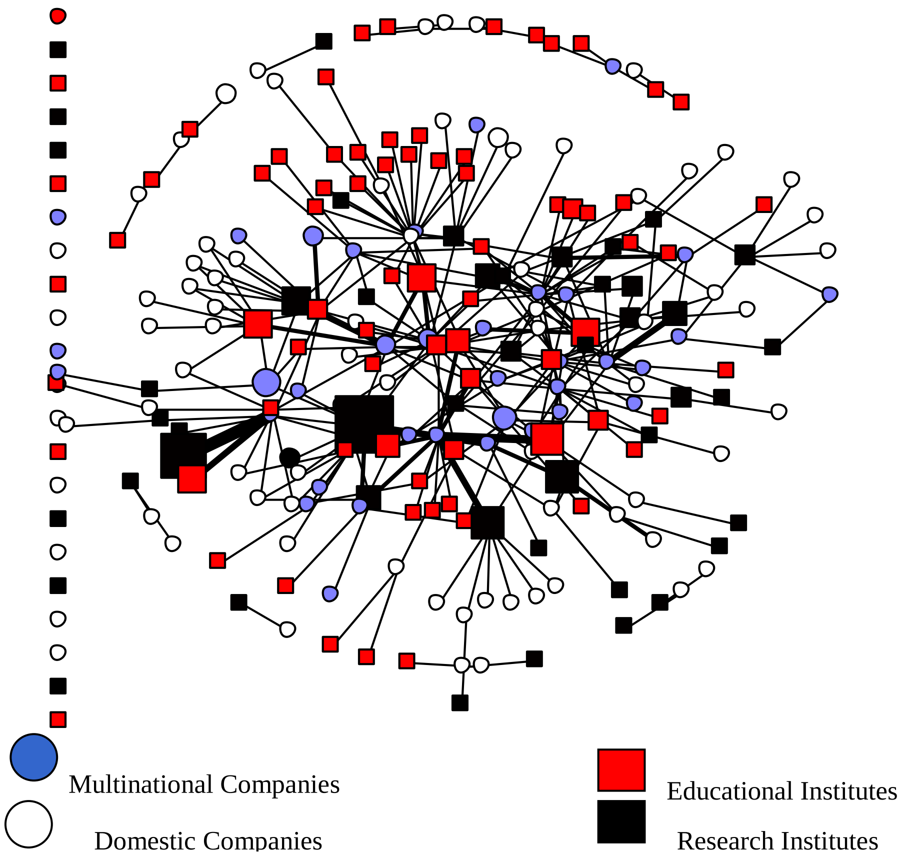
The network first analysed was the network formed by projects in research activities. This category aggregates the projects classified as research inside the innovation projects declared in the Brazilian ICT Law between 1997 and 2003. The research activities represented 4.8% of the total and the analysis of the research knowledge networks (see Figure 12a and Figure 12b).

Figure 12a provides a visual representation of the network formed by research activities. During the period under analysis, the ICT Law has involved an average of 109 projects per year with an average size of R$ 159’ that naturally involved a large number of technological fields and disciplines inside ICT. A total of 195 companies declared some sort of research activity, 111 with partnerships with 121 universities and institutes, summing up 315 ties (There are 23 ties stronger than R$1m developed in the sector).

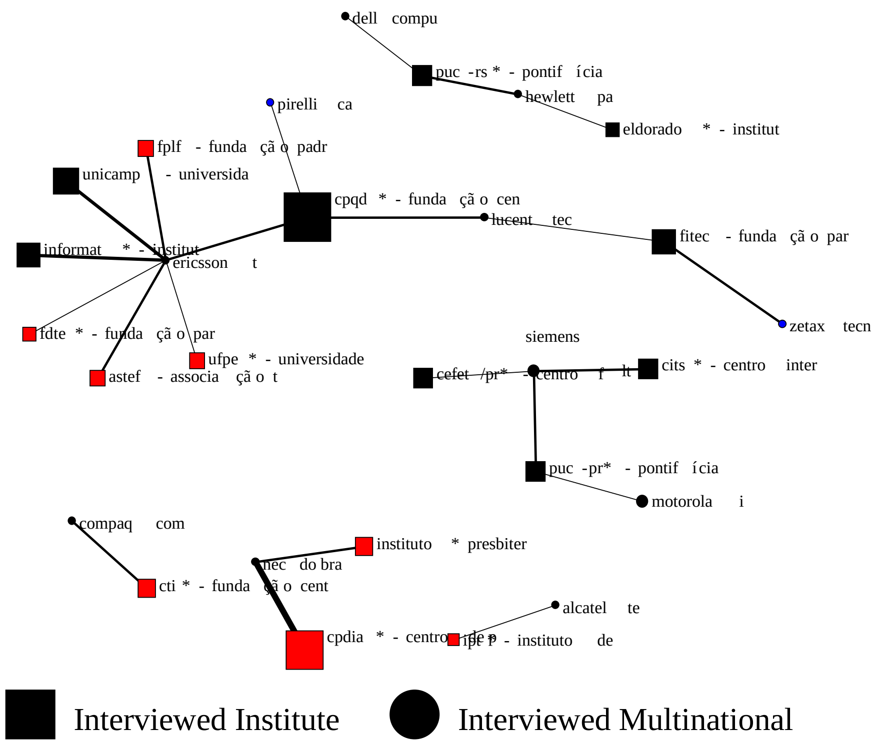
The total investments in partners during the period comprised R$97m (74% of the total in the category). The locus of the accumulation of technological capabilities was mainly internal to research institutes and universities. These investments created a wide network of relatively weak ties. The ratio of ties per total investment: the highest – 2.6 ties against the average of 0.5 ties in process and product development, demonstrate the importance of research related links in the creation of “weak ties”, or, at least resource-intensive ties.

Figure 12 – Knowledge networks in the Brazilian ICT sector in research activities - 1997-2003

(a) Complete



(b) Large Collaborations (>R$1million)



Source: Own elaboration based on MCT/SEPIN data using NetDraw 2.37. (Borgatti 2002)

Figure 12b represents the same network shown in Figure 12a but the ties involving less than R$1 million were filtered out. Large investments in research activities were an exception rather than the rule even among the selected interviewed companies. However, investments in technological partners did take place. The top 10 companies investing inside the Law were multinational companies and they were responsible for 84% of the investments inside the category. These investments were led by Ericsson and followed by NEC, Siemens and HP; these last two played a strong role in the last year of the analysis.

5.3.2. Laboratorial Infrastructure

Laboratorial infra-structure usually has an important role in the innovation studies and innovation policies given its widespread characteristics. Innovation is usually considered conditioned to the availability of fixed infra-structure and technological assets. As these projects are composed of irreversible investments that require long-term planning, the organisations emerging from these investments may enforce a path-dependence over time.

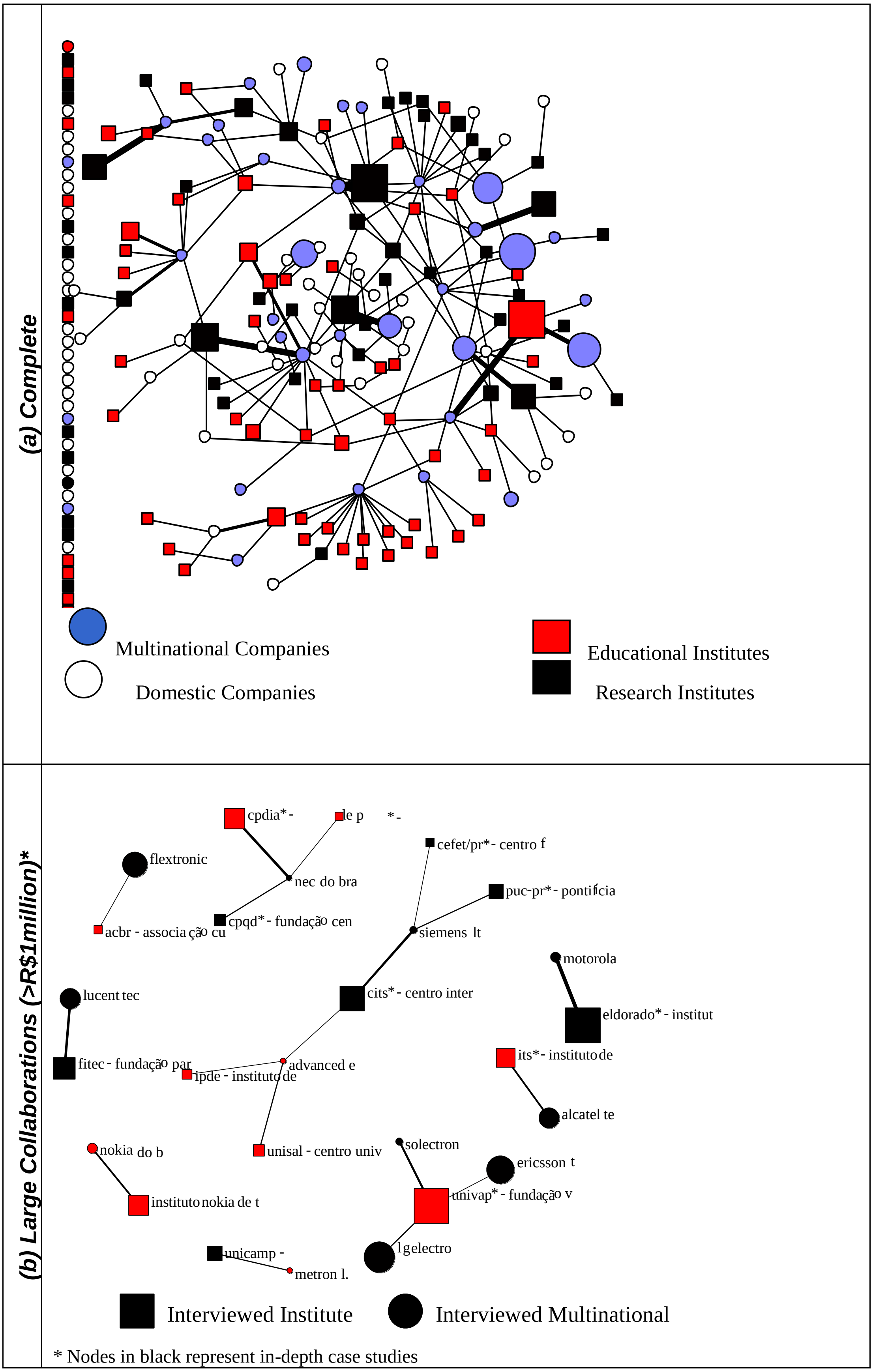
Inside the ICT Law, projects in infrastructure and modernisation of laboratories corresponded to 6.7% of the total investments. As shown in figure 13a, the ICT Law promoted a strong decentralisation of the infrastructure development that occurred through an average of 53 projects per year. In total, 140 companies developed projects of infrastructure and equipment for R&D activities. From this sample just 62 companies developed projects in partnership with 96 different universities and institutes.

The analysis of the filtered infra-structure network shows an opposing pattern. The analysis of the configurations among top investors shows the MNC's investing in new private research institutes (figure 13a and figure 13b). The top 10 investors in infrastructure and equipment were multinational companies, responsible for 77% of the investments in the category. The total investments conducted by the Top 10 companies shows a smooth skewdness in the relative importance of top 10 companies (individually, they represent between 11% and 7% of the total investment) (more details in Annex 5).

The projects have a temporary nature resulting in volatility over time. Motorola, Siemens, Alcatel, Ericsson and NEC had a very active role in the development of infrastructure and laboratory equipment during the four first years of the sampled period, while the LG, Lucent and Alcatel and Solectron (and Siemens to a lesser extent) had more importance during the last three years of the analysis.

There were important investments in technological partners. Among the top organisations, there were important research institutes that grew substantially during the period. Some collaboration agreements involved up to R$11.6m during the period, allowing the creation of proposed specific buildings. There were 18 collaboration agreements larger than R$1m related to the creation and improvement of infrastructure, mainly connecting private research institutes and different multinational companies.

Figure 13 – Knowledge networks in the Brazilian ICT sector in Laboratorial Infrastructure projects - 1997-2003



Source: Own elaboration based on MCT/SEPIN data using NetDraw 2.37. (Borgatti 2002)

These research institutes usually had a sponsorship from one of the large multinational companies (CPDIA was sponsored by NEC, CITS mainly by Siemens, Eldorado by Motorola, FITEC was sponsored by Lucent).

5.3.3. Training in S&T

Projects in personnel training in science and technology corresponded to 6.3% of total investments between 1997 and 2003 in an average of 87 projects per year. In general, these projects refer to general training programmes not directly connected with any specific output in terms of product development.

The visual analysis of figure 14 suggests that most of the training projects were outsourced. The incentives seem to have promoted a decentralised company-university interaction as an average of 70% of the projects was subcontracted. The total expenditure of R$100m with technological partners resulted in an average tie strength of R$ 388’[26]. There was also a private research institute that received an important part of the investments in this area. Institute Eldorado, supported mainly by Motorola, developed a central role in the knowledge network related to training in the sector. Nine multinational companies were among the top 10 investors in training (85% of the total).

Compaines also allocated resources to develop their internal capabilities. A considerable part of the training remained in-house (A significant 30% of the projects). Six multinational companies were among the top ten loci for training, indicating that the multinational companies have been key ‘schools’ in the sectoral innovation system. This might be reinforced by the high ratio of expenditure in travel costs, where personal were involved in training nationally and abroad.

5.3.4. Quality Systems

The projects in quality systems included mainly projects related to certification of R&D departments. However, there were changes in the definition and the investments in the category were restricted after 2001. In total, the projects defined as quality systems represented 4.8% of the total investments. For the period between 1997 and 2000, there was an average of 120 projects: each one costing an average of R$ 223’ annually. After the change in the definition, the number of projects dropped to 42 in 2001.

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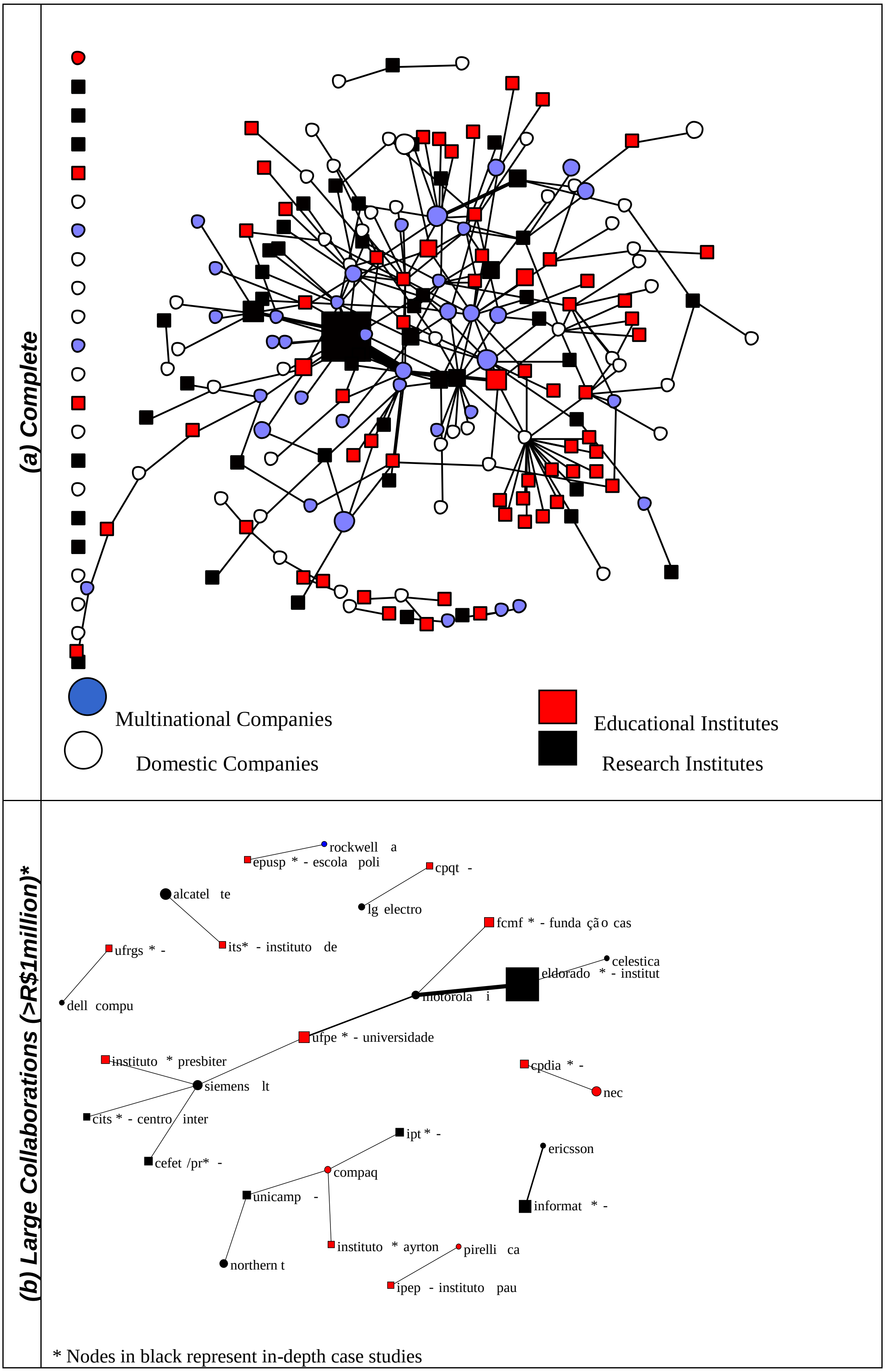
[26] Companies have naturally used other commercial partners related to training that are not listed (suppliers such as SAP, etc). Just certified partners (universities and institutes) are shown in this category. The use of other suppliers is classified as internal training.

Most part of the activities were developed in-house - an average of 77% of the total costs of the innovation projects- therefore, this represented few possibilities for the formation of knowledge networks and externalities to other firms (figure 15).

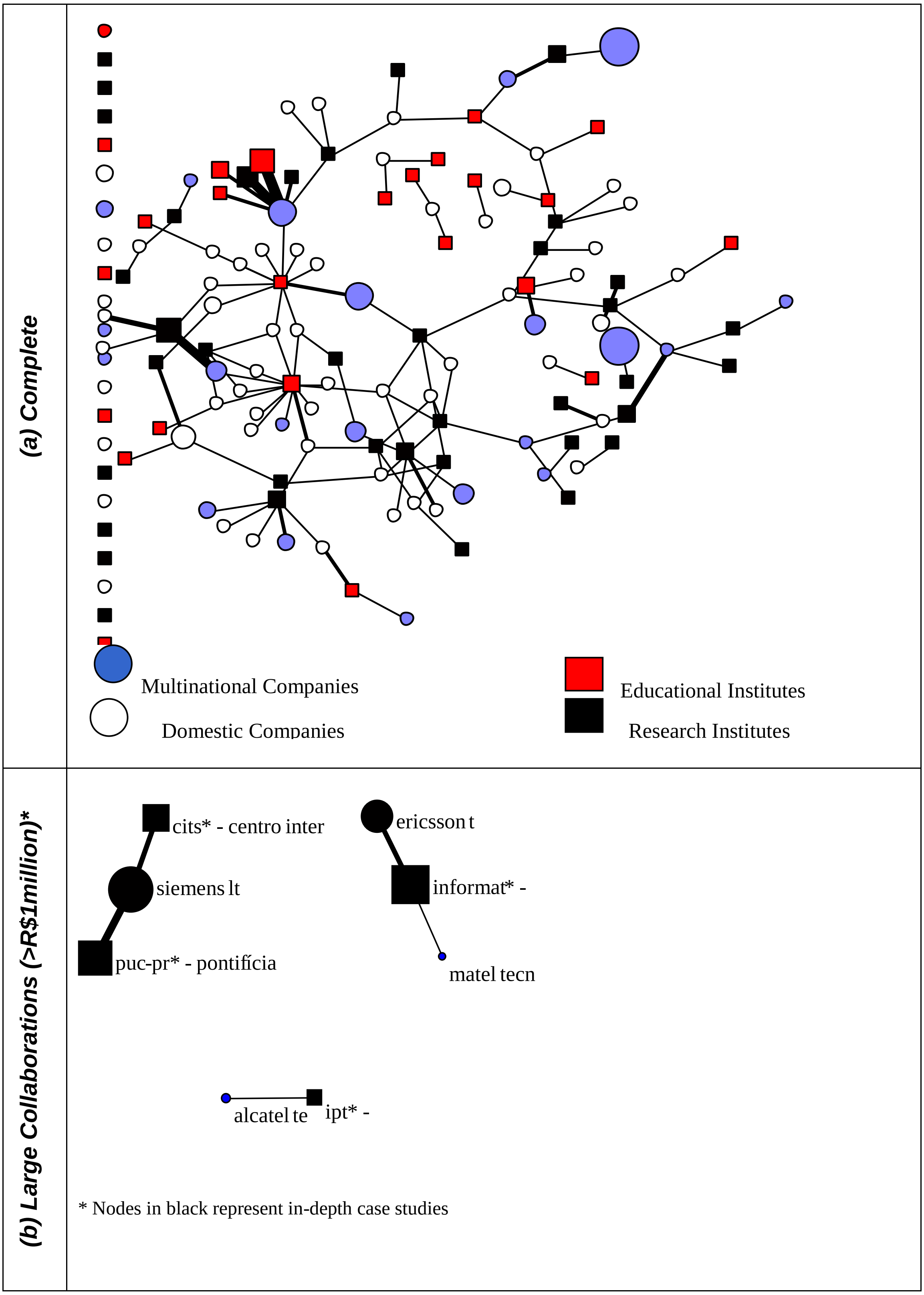
The density of the organisational network is low (105) and the 155 ties are relatively concentrated: just 85 out of 170 companies developed partnerships with only 54 partners. In general, companies tended to internalise projects in quality (77% of the total). The top 10 investors were multinational companies and they were responsible for 79% of the investment in this category.

Figure 14 - Knowledge networks in the Brazilian ICT sector in S&T Training projects - 1997-2003



Source: Own elaboration based on MCT/SEPIN data using NetDraw 2.37. (Borgatti 2002).

Figure 15 - Knowledge networks in the Brazilian ICT sector in Quality System projects - 1997-2003



Source: Own elaboration based on MCT/SEPIN data using NetDraw 2.37. (Borgatti 2002)

5.3.5. Technological Services

The projects related to 'technological services' refer mainly to the test and certification of newly developed products according to industry standards and regulations. The projects inside the database are just a small subset of the universe of technological services. Certification is required for any product introduced in the Brazilian market however, only the costs of the certification of new locally developed products can be assigned to this category. Hence, although the subset is limited, this is related to a representative part of the nationally developed products developed.

During the period under analysis there was an average of 57 projects per year valuing typically R$211' and comprising 3.4% of the total investments. In total, R$ 66m was spent with local partners on technological services. The network contains 76 firms connected to 71 partners through 170 ties, resulting in an overall density of 258 - an average of R$ 387 thousand per tie (figure 16).

Most of the partnerships involved relatively small amounts of resources, demonstrating a market-mediated interaction for specific services. In just three cases, companies invested more than R$1m in specific partnerships. Subsidiaries of multinational companies were key investors in this category as well (figure 16b). Although some equipment was retained internally by some subsidiaries, firms generally tended to outsource their needs in terms of technological services.

5.3.6. Product Development in Semiconductors

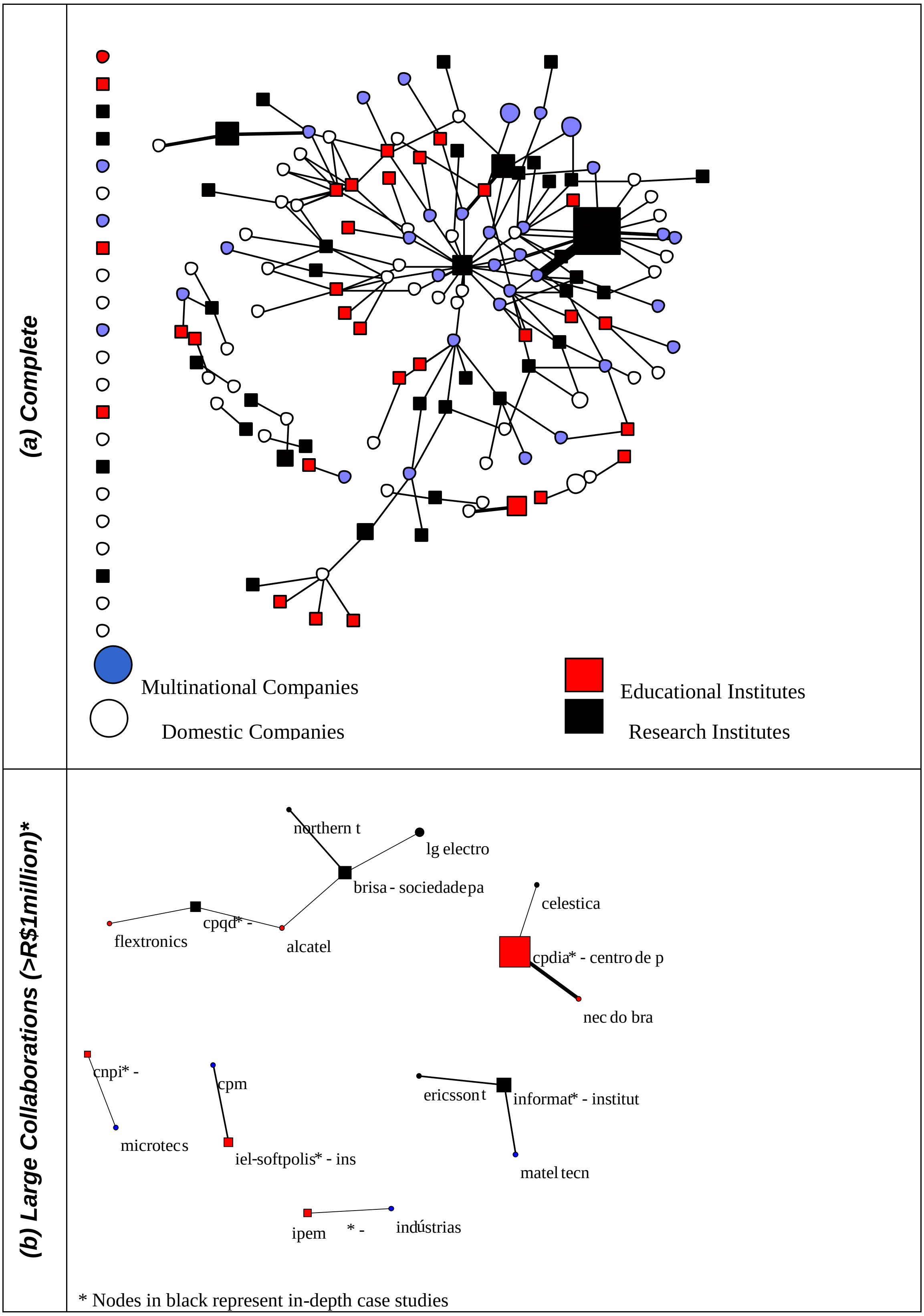
The first group of product development projects to be analysed are the projects related to the development of semiconductors. Although it has grown in importance during the period - in absolute terms, with a total investment of R$14.3m in 2003 - this was clearly the smallest trajectory in the Brazilian ICT sector with an average of just 6 projects per year (Semiconductors represents 1.8% of the investments inside the Law during the period).

The incentives so far have had a relatively weak effect on the development of this trajectory. A total of 30 companies declared projects of components. From this sample, half of them worked in partnership with 18 partners, resulting in 24 ties with a tie strength on average of just R$189' (figure 17). Among them, just one was over the stipulated threshold. As represented by the low density (17), the number of interactions among the existing companies in the sector was very low.

Some universities and research institutes participated in the development of capabilities, but the lack of overall connection among nodes in the network seems to indicate little synergy among the nodes as well as with other larger trajectories. The lack of evident network spill-overs is also exacerabated by the highly vertically integrated nature of the projects (~90%).

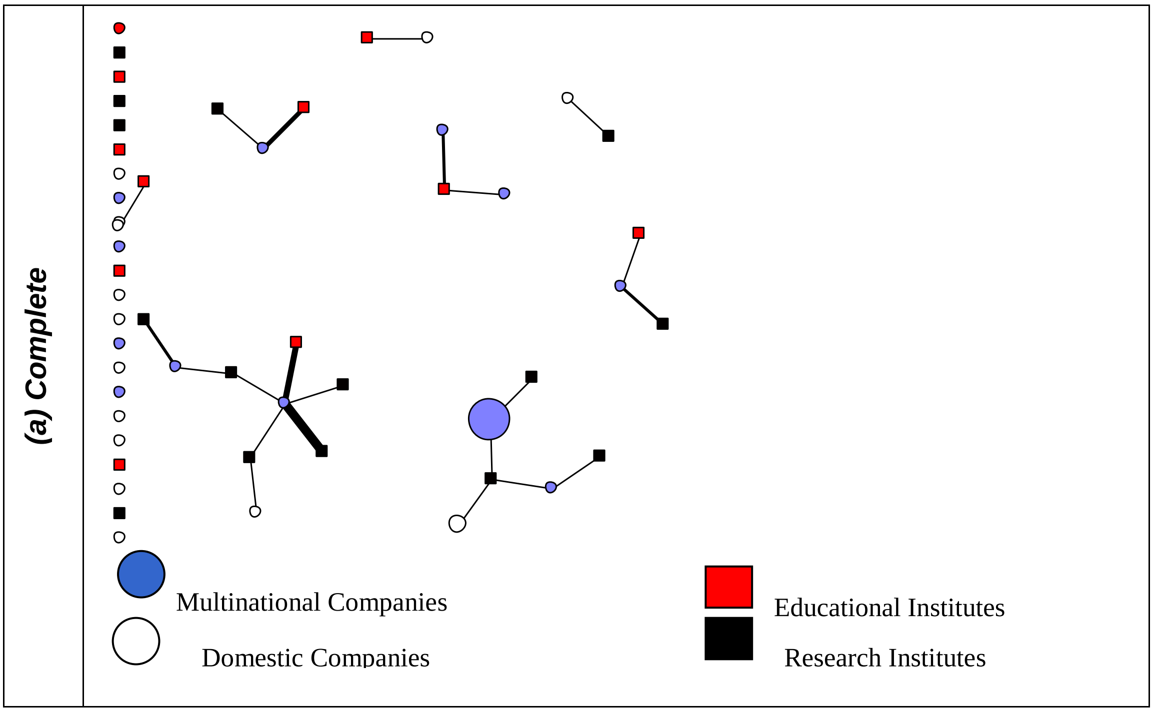
The top 10 investors represented 99% of the investments in the category and the most important multinational company, Motorola, represented on its own more than 70% of the total for the period. However, the importance of the top companies also varies over time. While NEC, Itautec and Ericsson (to a lesser extent) had an important role during the first period, they discontinued their investments in the last three years of the period. Motorola, almost alone, had a key role in developing this trajectory during the last period.

Figure 16 - Knowledge networks in the Brazilian ICT sector in technological services - 1997-2003



Source: Own elaboration based on MCT/SEPIN data using NetDraw 2.37. (Borgatti 2002)

Figure 17- Knowledge networks in the Brazilian ICT sector formed by innovation projects in semiconductor technology - 1997-2003



Source: Own elaboration based on MCT/SEPIN data using NetDraw 2.37. (Borgatti 2002)

5.3.7. Production Process Development

Similar to semiconductors, the innovation projects in production process represented a relatively small part of the total investments (4.3%). The many projects were sparse and mainly internalised. Differently though, these projects have had a decreasing importance over time. The average of 85 projects during the first period (1997-2000) had shifted towards an average of just 30 projects during the second period (2001-2003). Spillovers should be considered scarce as the innovation projects in production process had a very high level of vertical integration, varying from 72% to 96%. Just R$13.5m of the total R$108m was invested in partnerships, with an average strength of R$145'. The network that developed around supporting the production process was relatively sparse (Density 53) with just 54 partners connected to 44 companies (many cliques) (see Figure 18).

Again, all the top 10 companies were subsidiaries of multinational companies. Compaq and Motorola led the most significant initiatives during the early years, while Contract Manufacturer MNCs had strengthened their participation during the second period (the most important in terms of locus of innovation were Celestica, Flextronics, Solectron, and Jabil). This change reflected an evolution that occured in the production system installed locally, namely the establishment of second tier multinational companies in the second period and the subsequent increase in outsourcing of the first-tier MNC's to these companies.

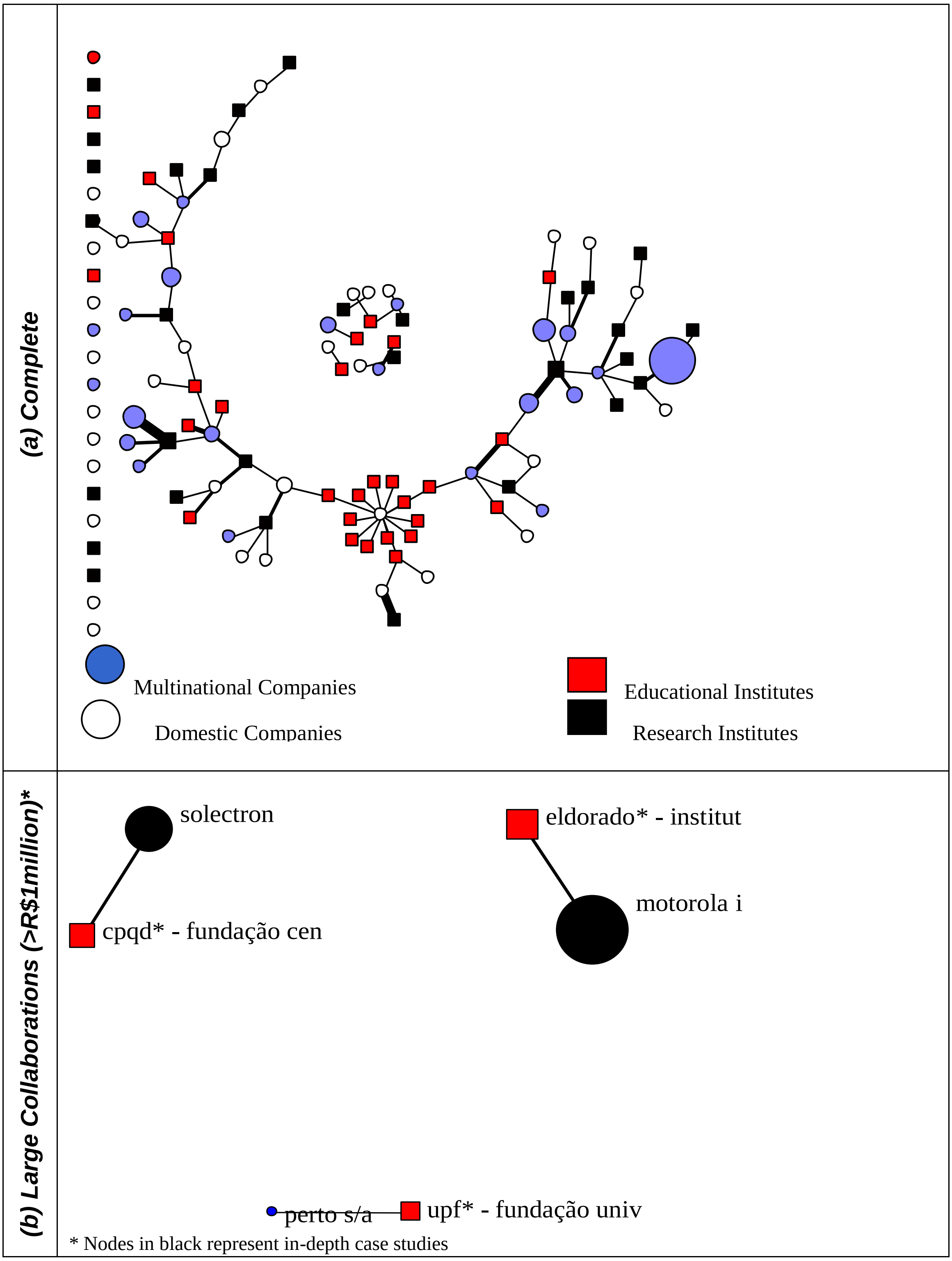
5.3.8. Product Development in Hardware

The following network is formed by projects in product development related to hardware. An average of 142 projects per year summed up an average of R$ 205m annually (Hardware represents 8.1% of the total investments). Despite the relative high investments in hardware, internalisation was very high and this promoted a relative low density (181) with a total of investments in partnership of R$46m.

The general network visualisation showed a rather fragmented network in general, with many cliques (isolated partnerships).A total of 191 companies invested in hardware. From this universe, 91 companies engaged in collaborative activities with 73 partners through 152 ties (figure 19).

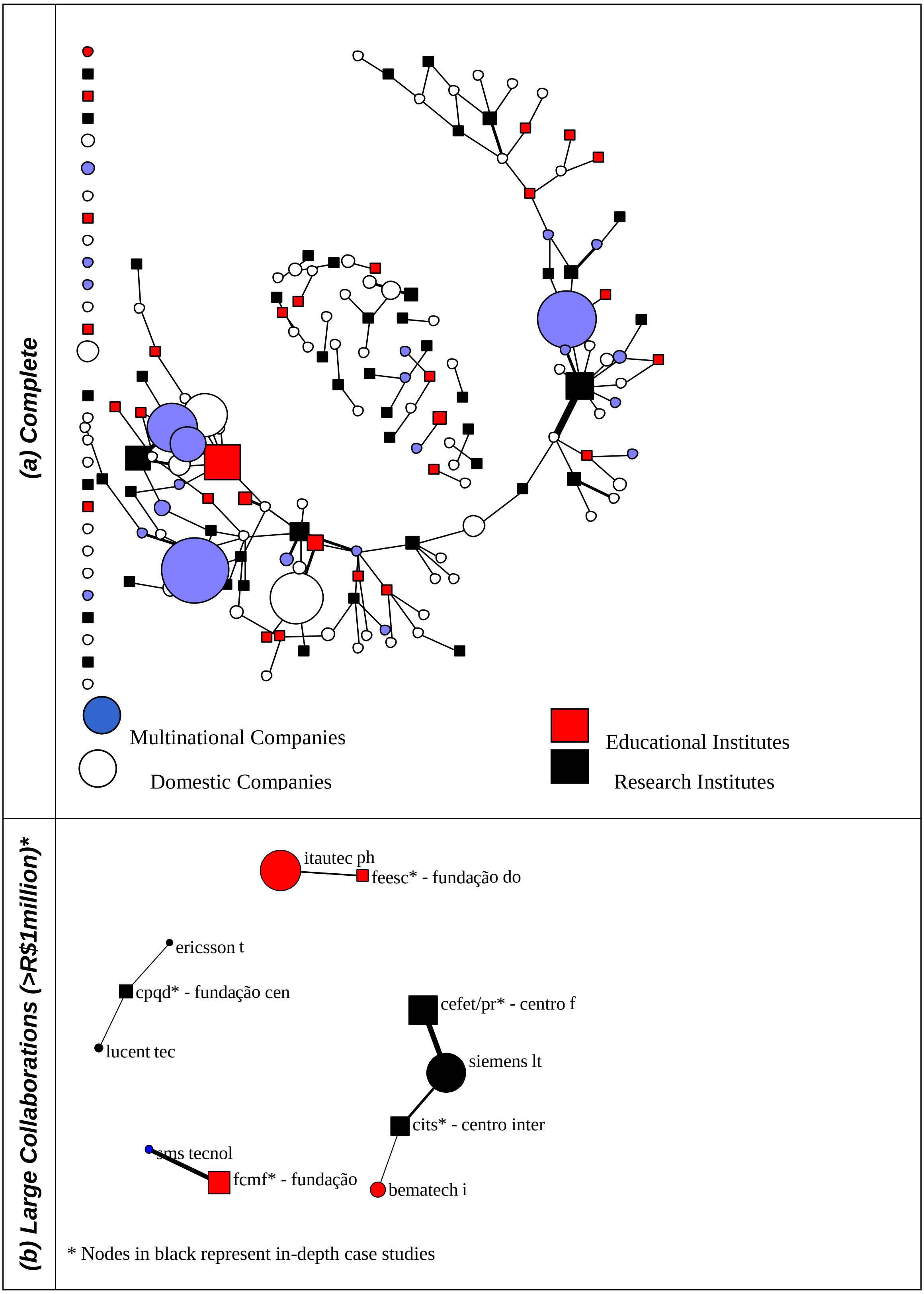
The top organisations involved in hardware were mainly companies, reflected in a high level of vertical integration of the projects (83% in average). There was a strong volatility in the role played by different actors during this time. The top ten initiatives involve five multinational companies and one joint-venture followed by three national companies. While Siemens, NEC and Itautec had important roles during the first four years of the analysis, Siemens decreased the number of projects in hardware while Motorola, Solectron and LG established important competences.

Figure 18 - Knowledge networks in the Brazilian ICT sector in production process projects - 1997-2003



Source: Own elaboration based on MCT/SEPIN data using NetDraw 2.37. (Borgatti 2002)

Figure 19 - Knowledge networks in the Brazilian ICT sector in hardware projects - 1997-2003



Source: Own elaboration based on MCT/SEPIN data using NetDraw 2.37. (Borgatti 2002)

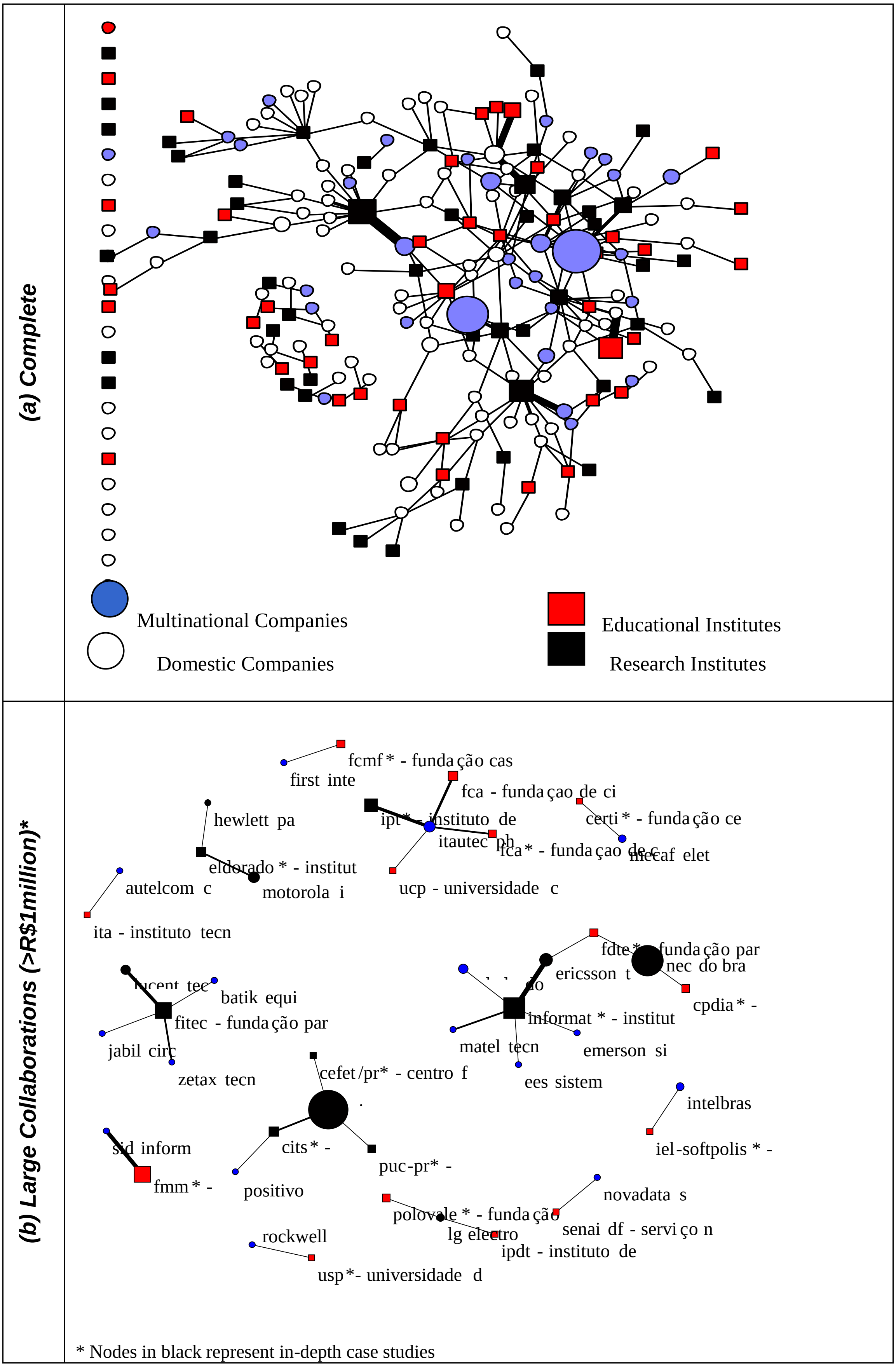
5.3.9. Product Development in Middleware

Investment in innovation projects, characterised as products involving middleware, formed the most important network in 1997 (35.3% of the total). However, there was a constant decrease in the investments in projects within this network (just 17.3% of the total in 2003).

There were many linkages between the nodes as shown by the general network (figure 20). The inter-organisation network is the second densest with 127 companies (out of 234 companies with projects in this category) interacting with 92 partners through 266 partnerships. The investments of local partners totalled R$ 212m and the average tie strength represented R$ 799’ (the main partnership represented R$ 28m).

The multinational companies were clearly the strongest group among the top 10 investors in this category. The exceptions were Itautec-Philco (a joint venture) and Sid (a local company that has an important partnership with IBM).The top 10 companies represented 84% of the investments inside the ICT Law for the period. Some of the companies had invested considerably though just during the first period (Ericsson, Sid Info, Motorola, IBM and Alcatel). Lucent had an important participation between 2001 and 2002. Meanwhile, Siemens, NEC, Itautec were active almost throughout the period.

Figure 20 - Knowledge networks in the Brazilian ICT sector in innovation projects related to middleware - 1997-2003



Source: Own elaboration based on MCT/SEPIN data using NetDraw 2.37. (Borgatti 2002)

5.3.10. Product Development in Software

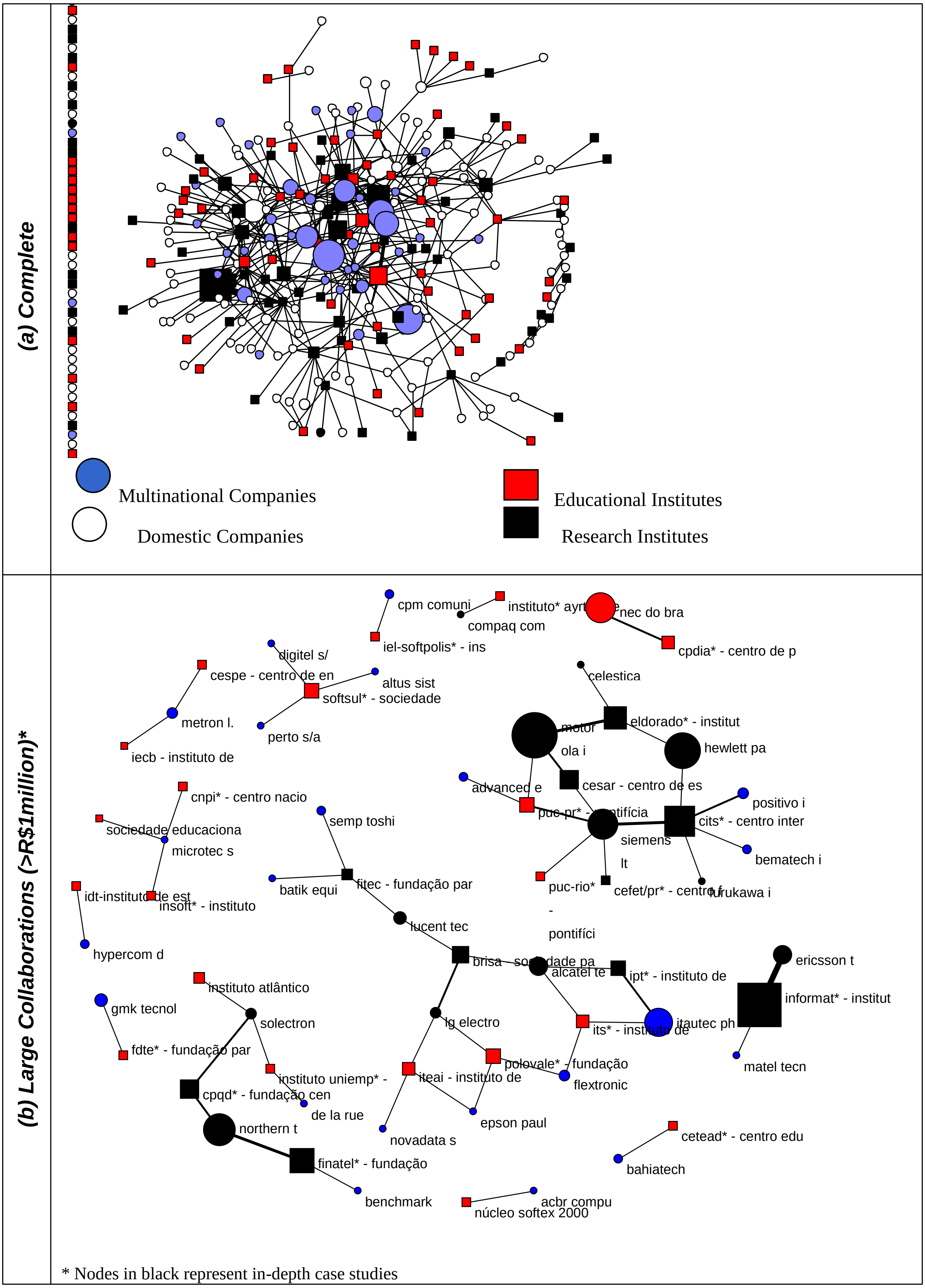
The analysis of the software network showed a significant growth. This became the most important trajectory with an average of 346 projects per year with investments growing from R$ 84m/year in 1997 to R$136.5m/year in 2003. In proportional terms, it represents a constant growth from 27.7% of the total investments in 1997 to 44.6% in 2003.

More than 271 firms developed projects classified as software development. From this sample, 157 companies have developed 140 partners in 464 different partnerships (figure 21). The investments with local partners summed R$ 385m with the average partnership involving R$ 830' and reaching to R$ 59 m. There were 56 ties greater than R$1m in this trajectory and, in some cases, suppliers developed strong ties with more than one multinational company. The inter-organisational network that developed is the largest and the densest (1512) given its large scope for knowledge spillovers.

To be specific, the analysis of the key-players showed the importance of multinational companies in the accumulation of technological capabilities in software. Among the top 10 investors (84% of the investments under the law), IBM, Siemens, Itautec-Philco[27] (a joint venture), NEC and Alcatel were precursors of the software trajectory. Throughout the time, Ericsson, Northern, HP and Motorola became the most important investors in software projects. The locus of the software development had been the companies themselves, and the private research institutes that emerged during recent years.

[27] The only exception among the top 10 investors – Itautec, Philco is a joint venture.

Figure 21 - Knowledge networks in the Brazilian ICT sector in innovation projects related to software - 1997-2003



Source: Own elaboration based on MCT/SEPIN data using NetDraw 2.37. (Borgatti 2002)

5.4. SUMMARY AND ANALYSIS

This chapter provides new empirical evidence of the structure of knowledge networks in the Brazilian ICT sector promoted by the Brazilian ICT Law. It shows the impact of the regionalisation policies on the intra- and inter-regional knowledge flows, the general characteristics of the network in different types of activities and the key role of some multinational companies and private research institutes.

This geographical visualisation of the network shows that there was an important agglomeration of technological activities in the Sao Paulo state, followed by the south and remaining states of the southeast. The changes implemented in the regulation promoted linkages between these regions and other states in the Midwestern, North and Northeast of Brazil. This analysis demonstrates the geographical concentration of the companies and institutions operating under the ICT Law - the limits defined by this research. It also describes some of the most significant changes in the institutional framework occurring during the period under analysis.

Finally, this chapter presents a descriptive visualisation of the knowledge network according to the type of activities. This initial analysis show important differences in terms of the structure of the networks formed in different activities in terms of boundaries between firms and institutes, patterns of specialisation and dynamic development. The knowledge networks in ten different types of activities are presented with limited level of detail in this chapter as they will be the main focus of the analysis in the subsequent three chapters. Chapter 6 compares in greater detail these structural characteristics of the network and chapter 7 explores in more detail the dynamic emerging in key nodes. Chapter 8 brings together these results in order to develop recommendations to promote the sustainability of these networks.

6. THE STRUCTURAL CHARACTERISTICS OF THE KNOWLEDGE NETWORKS

The previous chapter introduced the knowledge networks in ten different innovation-related types of project in the Brazilian ICT sector: laboratory and equipment infrastructure, technological training, technological services, R&D quality systems, process technology, product development in software, middleware, hardware and semiconductors as well as research activities.

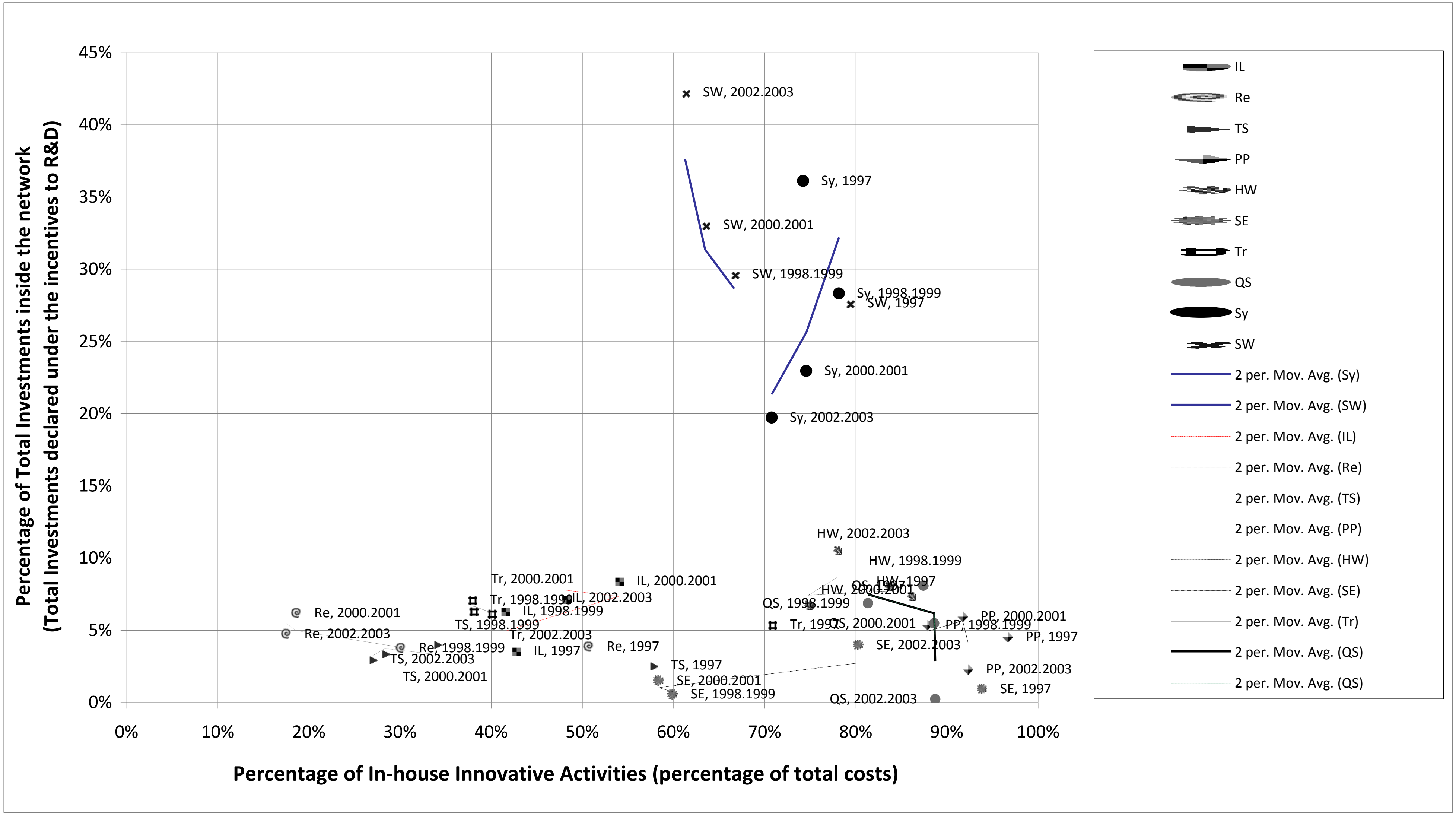
Following the elements of the theoretical framework for characterising the knowledge network between multinational companies and key technological partners (section 3.2), this chapter presents the results obtained from the empirical comparison of the knowledge networks in the Brazilian ICT sector in terms of the (i) boundaries between firms and technological partners in different knowledge-related activities, (ii) the specialisation in different governance mechanisms and (iii) the stability and change in the knowledge-based collaboration between different sets of actors. These three elements are respectively examined using, (i) a longitudinal examination of the boundaries between firms and technological partners in different types of innovation project, (ii) a project-based index of revealed technological advantage (PRTA) and (iii) a social network correlation technique (QAP).

6.1. THE ORGANISATIONAL BOUNDARIES

The first section examines the boundaries between companies and technological partners inside the project knowledge network. In section 3.2.1, it was argued that the balance between in-house and outsourced innovative activities is influenced by the knowledge base and the need to coordinate investments in the sector. This follows the procedure described in 4.3.1.

The graph in figure 22 portrays the networks according to their characteristics in terms of boundaries between companies and technological partners and the relative amount of investment in the different innovative activities in different moments in time. The vertical dimension is defined as the total investments in specific innovative activity in relation to the total investment. The horizontal dimension is defined as the total investment in internal projects in contrast to projects assigned to technological partners.

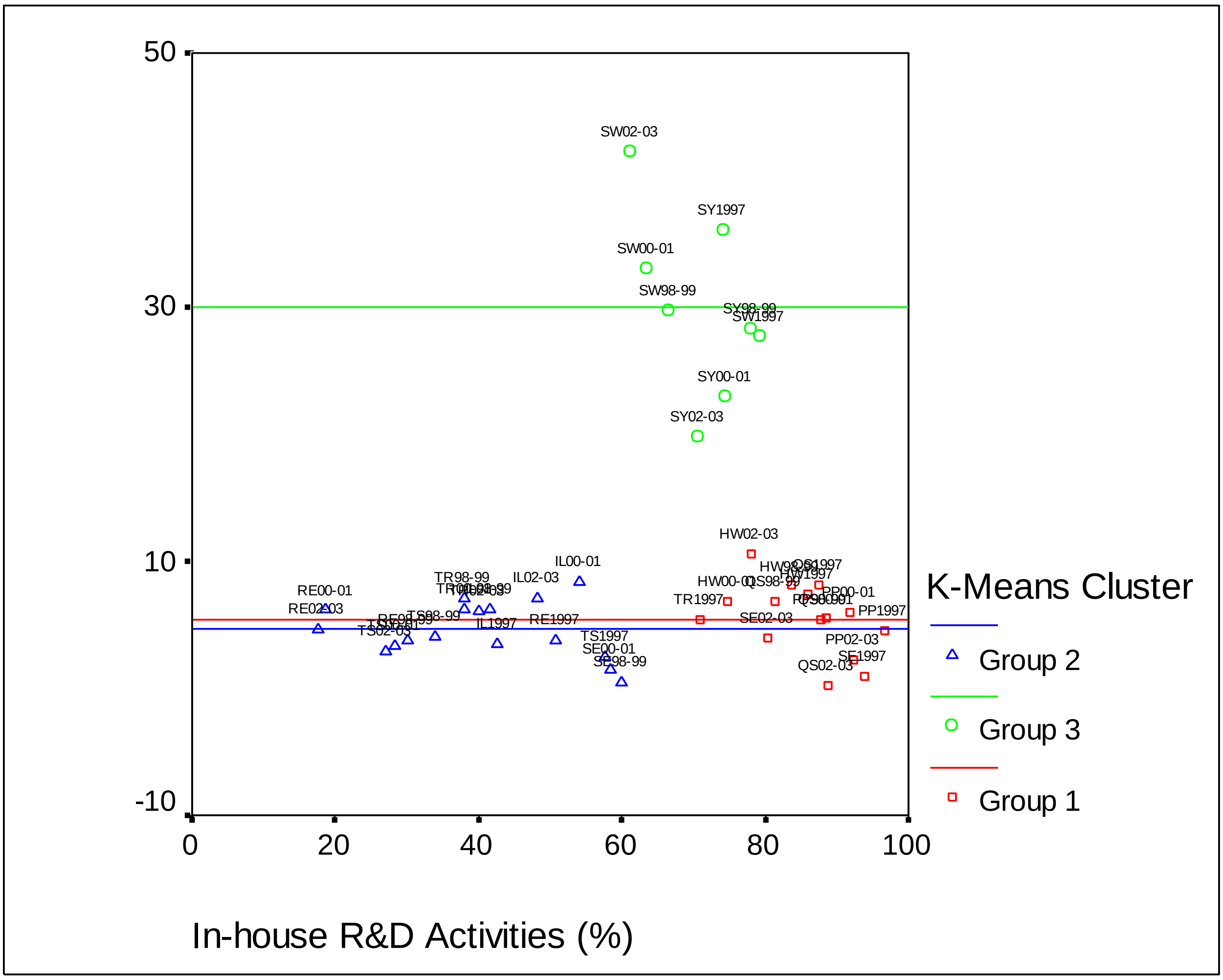
Figure 22 - The size and boundaries of the knowledge networks in the Brazilian ICT sector



A visual examination shows three different clusters. One group is formed by the networks in Software and middleware innovation projects. The second group is formed mainly by networks in the research, training, infrastructure and training services. The third group is formed mainly by networks working in hardware, production processes and quality systems.

A k-means procedure (a procedure used to automatically differentiate groups between k groups) indicates an initial robustness in this type of clustering (figure 23). The exception to this classification is the network formed by training activities in 1997 as well as the networks formed by semiconductors in 2000/01 which were located on the border between both areas.

Figure 23 – Clusters of knowledge networks



The different characteristics of these groups would allow the proposition of the following classification. There is a group related to semiconductors, production process, quality system and hardware characterised by low investments and high internalisation - called here *developing networks* - , a group formed by training, technological services, laboratories, and research, characterised by relative low investments and high-levels of outsourcing - called *enabling networks* - , and a group formed by software and middleware, that have relatively high investments and are mixed between in in-house and outsourced R&D activities –called the *developed networks*.

Table 11 shows the means of the different groups according to investments and boundaries. Table 11 also shows the classification according to the type of activities in a significantly different means: in terms of proportion of total investments and proportion of in-house innovative activities.

Table 11–Mean values of the different groups of knowledge networks

Group Statistics

Network Type		Mean	Std. Deviation	Valid N (listwise) Unweighted	Valid N (listwise) Weighted
Developing Networks (SC + QS + HW +PP)	Investments	.0490	.03090	16	16.000
	Internalisation	.8310	.11032	16	16.000
Developed Networks (SW+SY)	Investments	.2996	.07171	8	8.000
	Internalisation	.7106	.06686	8	8.000
Enabling Networks (Re + LI + Tr +TS)	Investments	.0512	.01731	16	16.000
	Internalisation	.3982	.14289	16	16.000
Total	Investments	.1000	.10780	40	40.000
	Internalisation	.6338	.23080	40	40.000

Tests of Equality of Group Means

	Wilks' Lambda	F	df1	df2	Sig.
Investments	.121	134.455	2	37	.000
Internalisation	.250	55.394	2	37	.000

For the purpose of this thesis, it is important to differentiate the structure in different networks according to the ownership of the companies in order to check whether these differences are consistent for both multinational and national companies. Table 12 shows the different points for both groups of companies. This classification is robust for investments in both multinational companies and national companies as shown in the test of equity of group means.

Table 12 - The Balance between in-house and outsourced R&D activities in different activities

Ownership			1997	1998/9	2000/1	2002/3	Average
Multinational Companies	Enabling Networks	In-house activities	39.86%	25.02%	26.52%	30.56%	30.49%
		Investments	3.41%	5.09%	8.58%	6.44%	5.88%
	Developing Networks	In-house activities	70.23%	59.59%	82.41%	70.93%	70.79%
		Investments	5.29%	7.11%	10.25%	8.37%	7.76%
	Developed Networks	In-house activities	81.73%	68.38%	65.20%	48.29%	65.90%
		Investments	28.95%	21.52%	22.83%	19.74%	23.26%
National Companies	Enabling Networks	In-house activities	57.54%	57.36%	26.25%	44.14%	46.33%
		Investments	5.57%	2.59%	4.19%	2.28%	3.66%
	Developing Networks	In-house activities	82.64%	86.00%	66.07%	89.90%	81.15%
		Investments	9.49%	6.09%	7.22%	5.46%	7.06%
	Developed Networks	In-house activities	57.95%	54.11%	46.00%	65.09%	55.78%
		Investments	19.80%	18.87%	17.40%	25.56%	20.41%

Group Statistics

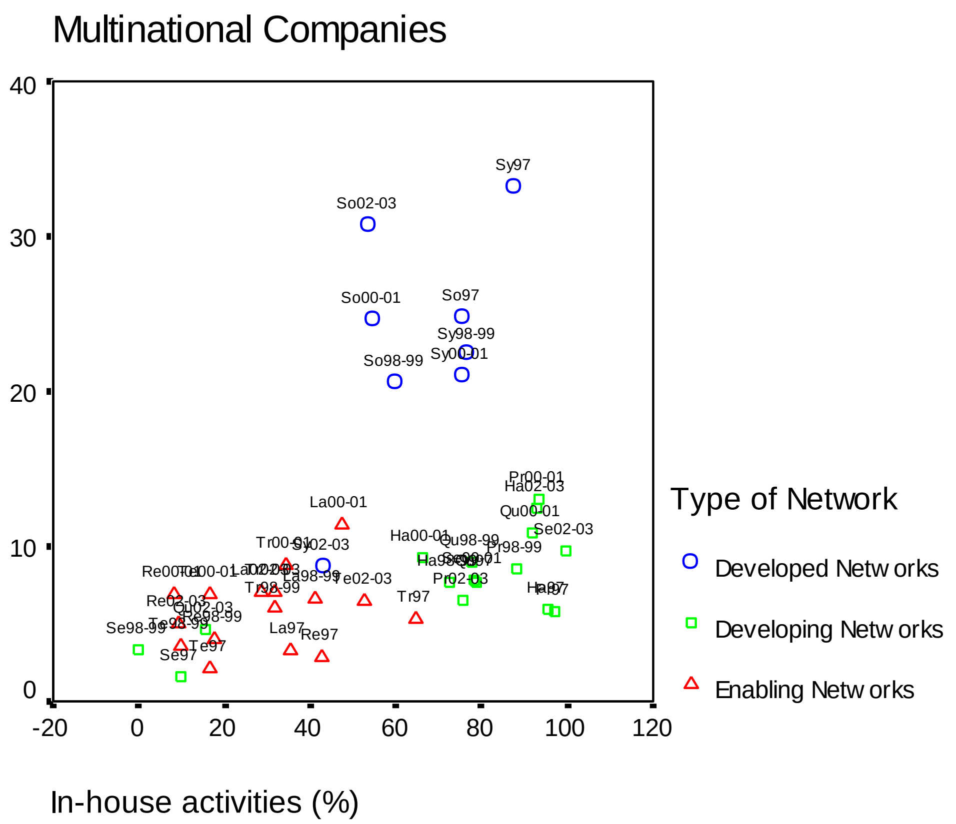
					Valid N (listwise)	
Ownership	Type of Network		Mean	Std. Deviation	Unweighted	Weighted
MNC	Enabling Networks	Investments	5.8819%	2.39260%	16	16.000
		Internalisation	30.4906%	16.67834%	16	16.000
	Developing Networks	Investments	7.7568%	3.08835%	16	16.000
		Internalisation	70.7923%	32.54031%	16	16.000
	Developed Networks	Investments	23.2626%	7.38112%	8	8.000
		Internalisation	65.9004%	15.18722%	8	8.000
	Total	Investments	10.1080%	7.79360%	40	40.000
		Internalisation	53.6932%	30.44715%	40	40.000
National	Enabling Networks	Investments	3.6577%	1.85630%	16	16.000
		Internalisation	46.3253%	19.77257%	16	16.000
	Developing Networks	Investments	7.0635%	4.86017%	16	16.000
		Internalisation	81.1523%	16.58178%	16	16.000
	Developed Networks	Investments	20.4060%	7.65509%	8	8.000
		Internalisation	55.7841%	13.02002%	8	8.000
	Total	Investments	8.3697%	7.77527%	40	40.000
		Internalisation	62.1479%	23.36094%	40	40.000

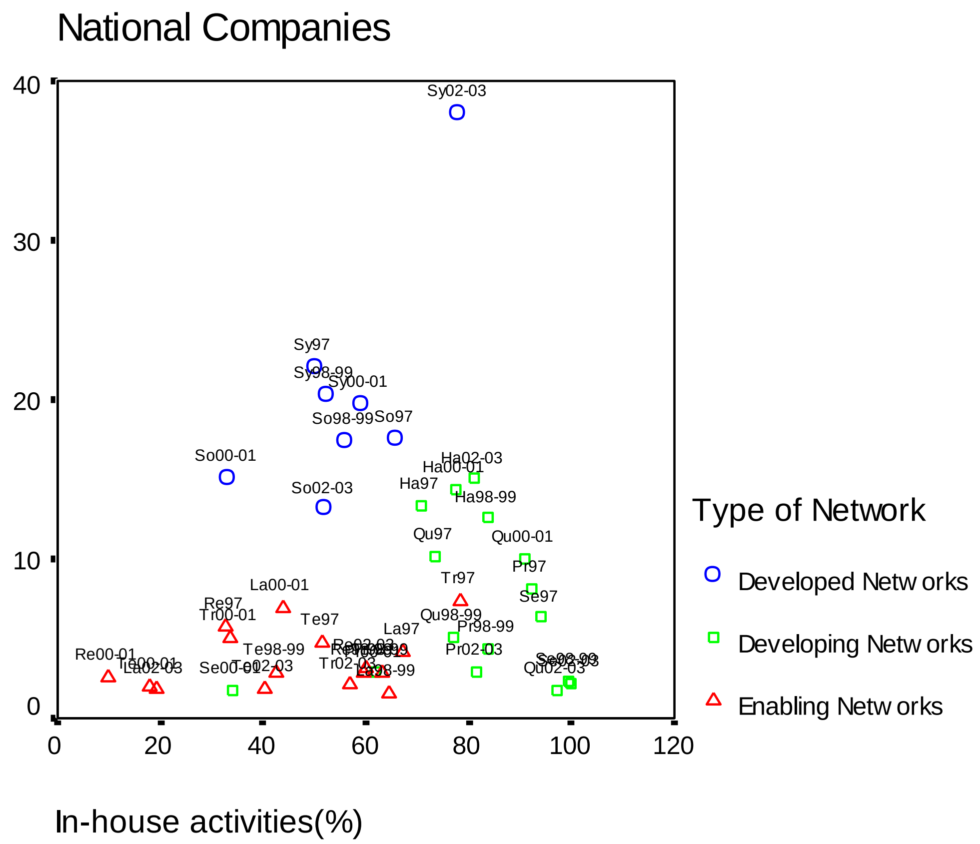
Tests of Equality of Group Means

Ownership		Wilks' Lambda	F	df1	df2	Sig.
MNC	Investments	.258	53.307	2	37	.000
	Internalisation	.599	12.365	2	37	.000
National	Investments	.346	34.940	2	37	.000
	Internalisation	.525	16.734	2	37	.000

These results show that the general pattern of the boundaries between firms and technological partners hold for the boundaries of both multinational and national companies. Figure 24 provides a visual inspection of these different company groups at different periods of time.

Figure 24 – Proportional investments and balance between in-house and outsourced innovation activities in developed, developing and enabling networks





The following patterns can be summarised from the results presented in this section..

Enabling networks (Low levels of investment, low vertical integration) – The group of points at the bottom right refers to activities such as training in science and technology, technological services (e.g. metrology, certification) and research activities. Investments within innovation projects tended to be smaller and almost entirely outsourced. Companies, particularly multinationals, tended to use the market in these innovative activities with comparatively lower investments. While just 30% of the resources allocated by multinational companies were in-house innovative activities, more than 46% of the resources were internalised in the case of national companies. Only a small part of the investments in technological services (36%), training in S&T (45%) and research activities (22%) were conducted internally. To some extent, investments in infrastructure and laboratories could also be associated with this group although they have a less significant difference in terms of firm boundaries (46%).

Developing networks (Low levels of investment, high vertical integration) - The points at the bottom left were mainly composed of three groups of innovation activities: product development using hardware, semiconductors, production process technology as well as quality systems. Companies, both multinational and national, tended to conduct most of their product development projects in-house whenever total investments were limited in specific technologies (71% and 81% respectively). Although some linkages could exist with international partners or other stakeholders, horizontal collaborations with partner technological institutions were limited.

There are also very different trends as shown by the longitudinal analysis. The trend in semiconductors shows incipient, but increasing, initiatives to accumulate technological capabilities inside the companies. An opposite trend is observed in relation to production technology that has decreased and outsourced activities. The observations related to hardware show that there is an upward movement, although it has been turbulent throughout the period, probably as a result of the instability in the initiatives undertaken by different companies in this type of technology.

Developed networks (High levels of investment, intermediate vertical integration of innovative activities) - A different portrait could be developed concerning the dynamic involving the two largest networks: the networks formed by product development projects using middleware and software technology, as both are characterised by higher levels of investment and an intermediate level of desegregation of activities between hierarchies and partnerships.

The analysis of these trends over time shows that the development of the network evolved in opposite directions. From this trend, we can see that the multinational companies have shifted their investments from middleware to software during this period. This behaviour was not imitated by national companies. In the middleware-related capabilities, an ever increasing part of the total investments in the technology started to be developed in-house, while in software capabilities, an increasing focus was put on outsourcing.

In the two large areas of investment (software and middleware), the data implies that there was considerable scope for both in-house and outsourced activities with technological partners. These lower levels of vertical integration in relation to other types of product development knowledge networks support the hypothesis that increasing resources available within the network are connected to the need for more coordination mechanisms.

This structure of the network supports both the importance of the type of knowledge base and the amount of investments in determining the boundaries between companies and technological partners. The evolution of the knowledge networks related to product and process development is mainly connected with endogenous growth of capabilities inside the companies and consequent need for coordination. The growth of the network related to training, technological services and research activities do not require the same level of internalisation. It suggests that firms have fewer, but stronger, ties in product development, while companies also tend to have more, but weaker, ties in relation to technological services, training and research activities.

6.2. FUNCTIONAL DIFFERENTIATION

A next step is to expand the analysis from the simply bilateral relation in terms of vertical integration, to the analysis of the emerging role played by different actors inside the knowledge network. As discussed in section 3.2.2, the exact function performed by different groups of actors in the innovation system is a result of the co-evolutionary process in each sector. Despite some similarities, authors differ substantially concerning the role played by multinational companies, different private and public research and educational institutes in a developing context in contrast to developed ones. This is however a crucial question to understand the innovation system. Indeed, the examination of the pattern of specialisation in the project knowledge networks can provide empirical insight in this direction.

Following the procedure described in section 4.3.2, Table 13 shows the measurement of the project-based technological revealed advantage (PRTA) for the different governance mechanisms.

Table 13 - Revealed Technology Advantage of the different organisational mechanisms

	Enabling networks				Developing Networks					Developed Networks	
Specialisation Index	Count	Research	Training	Infrastructure	Tech Services	Hardware	Semiconductors	Process	Quality	Software	Middleware
Foreign companies	51	0.25	0.72	0.83	0.42	0.96	**1.77**	**1.79**	**1.26**	**1.08**	**1.06**
Domestic companies	163	0.58	0.61	0.53	0.49	**2.18**	0.97	0.77	**1.64**	0.69	**1.38**
Private Research Institute	47	**1.33**	**1.46**	**1.31**	**2.39**	0.41	0.14	0.22	0.43	**1.17**	0.77
Public Research Institute	20	**3.08**	0.65	0.51	**1.57**	0.49	0.29	0.45	0.21	0.89	0.73
Private Educational Institute	75	**2.15**	**1.25**	**2.26**	0.98	0.17	0.02	0.20	0.67	**1.02**	0.97
Public Educational Institute	40	**4.98**	**3.39**	**1.55**	0.32	**1.85**	0.56	0.31	0.20	0.51	0.35

In this table, it is possible to observe patterns of specialisation in the different nodes, thereby identifying how the knowledge base was associated with different governance mechanisms in the network (i.e PRTA>1). Analysing the results, some patterns of specialisation emerged in the enabling, developing and developed networks.

The results show how different technological partners had a prominent role in specific enabling networks. Among the technological partners, private research institutes became key players in the different enabling networks (in research activities (1.33), training (1.46), technological services (2.39) and development of labs and technological infrastructure (1.31). Meanwhile, public research institutes became highly specialised in research (3.08) and technological services (1.57). It is possible to speculate on the organisational characteristics that define these differences. A possibly expected, educational institutes, both private and public organisations, specialised in similar areas such as research, training and infrastructure. (Public educational institutes, a group composed mainly of federal and state universities, were particularly specialised in the research and training areas (4.98 and 3.39 respectively). Most likely, the public organisations developed their comparative advantage from their traditional role inside the structured national educational system financed with public resources.

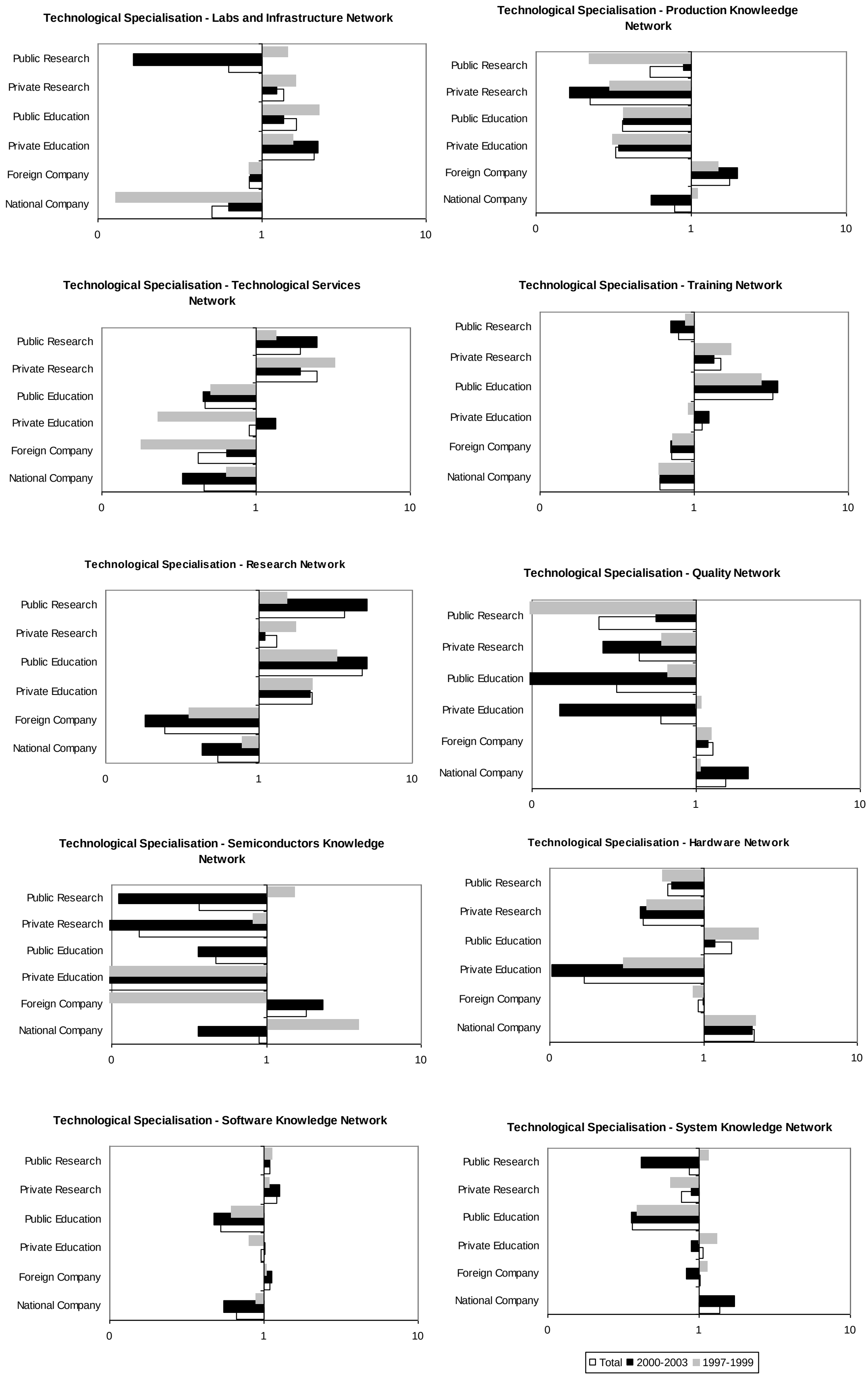
Companies had a particular role in development activities, both in developing and developed networks. Domestic companies focused their investments in middleware and hardware (as well, demonstrated relatively higher investments in quality systems), foreign companies were predominant in emerging software network (1.08 for multinational against 0.69 in domestic firms). The latter also undertook important initiatives in the semiconductors (1.77) and production process (1.79) activities. The results give a strong indication that while domestic companies tend to be more connected to their manufacturing base in hardware (2.18), multinational companies tend to be more capable of diversifying into distinct competences in middleware and software projects. The organisational characteristics of the MNC's may have allowed subsidiaries to develop capabilities in niches inside the international division of labour as a corporation operating on global projects and disconnecting themselves from the manufacturing basis and local market.

The differences between developed and developing networks is characterised by the increasing importance of technological partners, particularly private research institutes in this community. The participation of technological partners is clearly more prominent in these activities than in developed networks. The role of private research institutes (1.17) and, to a lesser extent, private educational institutes (1.02) in software is also worthy of notice. Their prominence demonstrates that these organisations have an important effect on this developed network, therefore, providing an important element for the coordination of knowledge related to product development.

The public nature of some technological partners seems to negatively affect their participation in product development. Traditional public institutes did not tend to diversify into collaborative activities in the new technological areas. The indication is that public funds tended to complement private investments in terms of technological services and the required research personnel for these activities, creating a relative comparative advantage for these activities. Meanwhile, the governance of these organisations and their policies could be too rigid to adapt to the short-term requirements of companies, as private research institutes became fundamental inter-organisational linkages in the software project-based networks.

In order to investigate the dynamic nature of the functional differentiation in the knowledge network, figure 25 shows the profile through different time periods (1997-2000 and 2001-2003).

Figure 25 - Functional differentiation in the knowledge network for two time periods



The graphs show that for most of the combinations between activities and groups of organisations, there is a relatively stable specialisation pattern for the different activities.

The groups of organisations that crossed the line which differentiates specialision from non-specialisation in specific activities during the period were (i) public institutions in the categories related to infrastructure and laboratories, (ii) national companies in production process, (iii) public research institutions and national companies in semiconductor activities, (iv) public research institutes, private educational institutes and foreign companies in the middleware network.

The groups of organisations that crossed the line from non-specialist to specialist were: (i) private educational institutes in technological services, (ii) private educational institutes in training, (iii) foreign firms in semiconductors. (iv) private educational institutes in software.

The stability and change in these patterns of specialisation have interesting implications. First of all, the stability demonstrates the importance of path dependence in the knowledge network with its implications on the organisation of the innovation system. The stability also reinforces the validity of the general analysis discussed earlier in this section. At the same time, the occurring changes provide important indications of exceptions and trends in the overall reorganisation of the innovation in the sector. Further qualitative research should help corroborate these patterns (chapter 7).

6.3. COLLABORATIVE INNOVATIVE ACTIVITIES

Another crucial empirical question in the characterisation of knowledge networks is the investigation of its speed of change in the collaborations inside the network. As pointed out in section 3.2.3, some authors argue that these are relatively stable over time given the lengthy periods of time required to accumulate significant technological capabilities. Others have argued that the different organisations quickly recombine their partnerships following specific strategic needs and changes in the environment.

An empirical examination of the speed of change in the project-knowledge networks can inform our understanding of how companies exploit and explore technological niches as based on a QAP method (described in section 4.3.3), Table 14 and 15 show the correlation between the knowledge networks in different years considering binary and valued ties respectively. As could be expected, there is a slow decrease in the correlation among the networks as they are further apart in terms of time. If binary values are considered, the correlation in consecutive years varies from a maximum of 0.63 between 1998 and 1999 and a minimum of 0.33 between 2001 and 2002. Even stronger correlations are observed when the valued ties in the network are considered (up to 0.88 between 1998 and 1999). The exception is between 2000 and 2001 when a change in the legislation including regionalisation requirements for the partners caused sconsiderable disruption. (The correlation was just 0.17, showing considerable disruption).

Table 14 - Longitudinal correlation in the project-base knowledge networks in the Brazilian ICT sector - (binary ties)

	b97	b98	b99	b00	b01	b02	b03
b97	*1.00*						
b98	0.49	*1.00*					
b99	0.37	**0.63**	1.00				
b00	0.26	0.38	**0.50**	1.00			
b01	0.13	0.23	0.30	0.48	1.00		
b02	0.09	0.16	0.16	0.28	0.33	1.00	
b03	0.06	0.10	0.10	0.18	0.22	**0.52**	1.00

Table 15 - Longitudinal correlation in the project-base knowledge networks in the Brazilian ICT sector - (valued ties)

	a97	a98	a99	a00	a01	a02	a03
a97	1.00						
a98	**0.88**	1.00					
a99	**0.67**	**0.79**	1.00				
a00	0.67	0.71	**0.83**	1.00			
a01	0.17	0.19	0.14	0.18	1.00		
a02	0.47	0.47	**0.60**	**0.71**	0.38	1.00	
a03	0.13	0.24	0.46	0.33	0.10	**0.53**	1.00

A relevant aspect of these correlations is the fact that the structure of the network changed very substantially during the observed seven year period. As shown in the correlation between 1997 and 2003, the correlation between the two networks is less than 0.06 points if the binary network is considered, or 0.13 points if the valued ties are used. This indicates that a substantial transformation in the patterns of collaboration occurred in the sector during the period under investigation.

Although in part, path dependence in the partnerships did exist in the sector, a high-level of volatility in the project-based knowledge network is also clearly observed. The data indicates that considerable volatility was induced by changes in the legislation between the first and second half of the period. As could be expected, those periods with relatively stable legal framework had a stronger stability in the structure of the network. This, however, is not the only determinant as considerable changes also occured during years with stable legislation.

Another step in the analysis of the collaboration is the examination of the interconnection between the different knowledge flows that occur inside and among different project-based knowledge networks. Table 16 shows the result of correlation among the different valued networks using the payments within innovation projects as a proxy for knowledge flows among actors in different activities[28].

Table 16 – QAP Correlation among the knowledge networks developed in different activities

		Enabling Networks				Developing Networks				Developed Networks	
		ninfra	ntrain	nser	nres	ncomp	nhard	nproc	nqual	nsof	nsys
Enabling Networks	ninfra	1.00									
	ntrain	**0.58**	1.00								
	nser	0.28	0.17	1.00							
	nres	0.33	0.18	**0.62**	1.00						
Developing Networks	ncomp	0.05	0.04	0.10	0.31	1.00					
	nhard	0.16	0.10	0.04	0.24	0.15	1.00				
	nproc	0.45	**0.67**	0.15	0.20	0.14	0.24	1.00			
	nqual	0.28	0.20	0.20	0.36	0.09	0.21	0.20	1.00		
Developed Networks	nsof	0.31	0.45	0.33	0.37	0.07	0.16	0.30	**0.58**	1.00	
	nsys	0.26	0.27	0.21	0.29	0.06	0.14	0.16	0.42	**0.60**	1.00

**All the correlations are significant at 0.01.*

QAP procedure developed in UCINET 6 (Borgatti 2002)

[28] See section 5.3 for the visualisation of the networks.

The first clear result of the correlation is that the knowledge flows inside the project-based networks are not homogeneous therefore the proposition is supported: different types of knowledge bases require specific types of inter-organisational channels. Although the relationship between the different activities does exist, most of the networks presented are significantly different from each other as demonstrated by the relatively small correlation between the different networks in most cases. Different knowledge activities would create significantly different communities of practice that could co-evolve in the sector.

The second set of results with empirical relevance refers to those networks that do have a relatively strong correlation. Establishing 0.5 as an arbitrary threshold to a strong relationship, just five intertwined networks could be distinguished. These intertwined networks could be further grouped into three distinct communities of practice:

- The first strong correlation is between collaborations in training and Infrastructure, and training and Production Technology. The analysis suggests that companies connected with the same partners for the improvement of the infrastructure and for training in new technologies. In addition, production technology was also particularly related to training in new technologies.
- The second strong correlation is between collaborations in research and technological services. Other channels became specialised in providing research activities and technological services (metrology) for the companies. It is interesting to note that, in general, research and technological services (possibly centres of excellence in different technologies) were not strongly related with the linkages involved in product and process development.
- Finally, there are strong linkages between collaboration in product development in software and quality systems and software and middleware. Specific channels became related to the improvement of quality systems in R&D (e.g. CMM certification) and the development of products in software. Here, it is also possible to observe a strong relationship between the formation of the capabilities in middleware and software. Although this test does not allow us to attribute causality, the dynamic changes shown in table 16 reinforce the interrelation between the decreasing middleware project network and the growing software project network. While the newcomers (especially multinational companies) shifted their investments towards opportunities in software, private research institutes became key integrators between ‘old’ and ‘new’ opportunities.

Similar to the previous analyses in this chapter, a necessary distinction is made between the behaviour of the network emerging from multinational companies and the network developed around national companies. Table 17 shows the correlation among the different knowledge networks emerging from foreign companies, and table 18 shows the correlation among the networks in different knowledge-related activities developed around national companies. These results clearly demonstrate that the general pattern observed in table 16 is largely defined by the behaviour of the large multinational companies. The multinational companies have shown even stronger connection between collaboration in infra-structure and training (it increased from 0.58 to 0.59), training and process (increase from 0.67 to 0.69), between services and research (an increase from 0.62 to 065), and between quality and software (from 0.58 to 0.62).

The most impressive increase is related to the connection between software and middleware activities that moved upwards from 0.60 to 0.78, showing how these two activities are fundamentally connected to the group of multinational companies. In addition, the connection between quality and middleware networks reached 0.53 and surpassed the arbitrary limit defined among the multinational companies, showing the importance of certification and quality systems to the partners of multinational companies in both developed networks (middleware and software).

On the contrary, domestic companies do not show any strong correlation with the different networks (Table 18), again arbitrarily defined as 0.5. These results strongly contrast with the networks among foreign companies. Possibly, this is in a large part a result of the community of foreign companies having more resources and having the ability to participate in different communities of practice. They are also a smaller, more homogeneous group than the national companies. Given the focus of this research on the linkages among foreign multinational companies and their integration with local innovation system, the investigation will not further pursue the isolation of other variables such as size that could explain these differences and pave the way to more generalisable results. Sufficient at this point is the identification that these networks are indeed different in this specific sector and the foreign multinational companies are key nodes coordinating knowledge in different communities of practice.

Table 17 – QAP Correlation among the knowledge networks developed in different activities restricted to linkages from foreign companies.

		Enabling Networks				Developing Networks				Developed Networks	
		MnInfra	MnTrai	MnSer	Mnres	Mncomp	MnQual	Mnpro	Mnhard	Mnsoft	Mnsys
Enabling Networks	MnInfra	1.00									
	MnTrai	**0.59**	1.00								
	MnSer	0.29	0.17	1.00							
	Mnres	0.35	0.18	**0.65**	1.00						
Developing Networks	Mncomp	0.06	0.04	0.10	0.32	1.00					
	MnQual	0.30	0.21	0.18	0.38	0.09	1.00				
	Mnpro	0.46	**0.69**	0.15	0.21	0.14	0.21	1.00			
	Mnhard	0.20	0.12	0.04	0.28	0.20	0.28	0.32	1.00		
oped Netw orks	Mnsoft	0.32	0.46	0.34	0.39	0.07	**0.62**	0.32	0.20	1.00	
	Mnsys	0.37	0.37	0.29	0.39	0.08	**0.53**	0.21	0.19	**0.78**	1.00

Table 18 – QAP Correlation among the knowledge networks developed in different activities restricted to linkages from domestic companies.

		Enabling Networks				Developing Networks				Developed Networks	
		Nninfra	Nntra	Nnser	Nnres	Nncom	Nnpro	Nnqual	NnHar	Nnsys	Nnsoft
Enabling Networks	Nninfra	1.00									
	Nntra	0.02	1.00								
	Nnser	0.00	0.37	1.00							
	Nnres	0.03	0.37	0.07	1.00						
Developing Networks	Nncom	0.00	0.00	0.00	0.01	1.00					
	Nnpro	0.02	0.05	0.07	0.09	0.00	1.00				
	Nnqual	0.00	0.26	0.40	0.11	0.06	0.11	1.00			
	NnHar	0.03	0.23	0.02	0.23	0.01	0.03	0.04	1.00		
Develo ped Networ ks	Nnsys	0.01	0.05	0.07	0.17	0.01	0.11	0.25	0.07	1.00	
	Nnsoft	0.03	0.18	0.20	0.08	0.00	0.07	0.22	0.06	0.43	1.00

The quantitative analysis of the structure of these communities of practice in this sector provides insights into the complex and multi-dimensional nature of the accumulation of knowledge inside organisations and the knowledge flows in sectors. Naturally, innovation projects involve many other types of interactions occurring inside the sector, for instance, through the interaction with customers, suppliers and other functions of the company inside and outside the sector. Even focusing on a subset of the relationships and activities inside the innovation process, this inductive approach shows how different types of organisations specialised in specific types of activities require particular channels for the diffusion of knowledge.

Given that a number of organisations may take the lead among the different activities and possible conflict of interests between these different organisations, the decentralised innovation projects in sectors remain strongly susceptible to network failures. Further, there are a constant opportunities for entrepreneurs inside and outside existing organisations to align interests with different networks.

6.4. ANALYSIS AND CONSIDERATIONS

A key challenge for innovation management and policy is a dynamic understanding of the relationships between the knowledge base of sectors, the main actors and the knowledge flows in sectors. This chapter contributes to the empirical literature on the organisation of sectoral innovation systems using innovation projects to examine three questions regarding the relationship between the knowledge base and the structure and dynamics of the knowledge networks in sectors. This chapter uses longitudinal analysis of the boundaries between firms and technological partners in different innovation activities, a project-based index of revealed technological advantage for different governance structures (PRTA) and social network correlation techniques (QAP) to identify a number of characteristics of the knowledge network co-evolving in the sector. The three distinct analysis show that rather than being cumulative (same actors going from basic training, to product development, to research activities), the development of the system is multi-dimensional, where different governance structures are involved in specific activities in a process of specialisation and differentiation.

The first section states that the knowledge base significantly influences the boundaries of the innovative activities as well as the endogenous availability of resources inside the network. The results indicate that project-based networks would emerge more naturally from activities such as research, training, technological services and infrastructure. In these activities, the natural trend would be the formation of market-mediated ties with a plethora of organisations accumulating capabilities and enabling networks in universities and public research institutes. Companies would be willing to maintain sporadic channels of interaction with many organisations in these activities. On the other hand, early initiatives in product development (developing networks) were associated with higher internalisation levels. A mixture of vertical integration and strong interaction with external partners was observed only in middleware and software (developed networks). In product development where a larger number of actors invested in the technology, an endogenous reconfiguration of the disperse capabilities inside the sectoral networks could be suggested.

The second section examines the process of specialisation of governance structures inside the project-based knowledge network in different activities. A great variety of organisations coordinated available resources in new opportunities forming complex inter-organisational sectoral governance structures. Domestic companies remained focused on hardware and middleware (close to manufacturing activities), while multinational companies (matrix R&D units) connected to private research institutes (project-based organisations) and were important in the emerging software technology. Public research centres and educational institutions (usually functional structures) became central in training and research activities. The different roles of these organisations reinforce the importance of diversity of the governance structures and the different mechanisms for interaction between public and private, as well as domestic and multinational stakeholders, inside the sectoral systems.

The third section examines the patterns in the collaboration between companies and technological partners through time, distinguishing between networks formed by domestic and multinational companies. The low correlation between the networks in different activities shows that the scope of the collaboration is usually limited to specific types of knowledge. There were, however, some wide ranging colaborations involving specific pairs of knowledge activities developed between multinational companies and technological partners. In particular, three distinct strong correlations emerged between different communities of practices: (i) production process and laboratorial infrastructure/equipments were connected with training, (ii) research was correlated with the same partners involved in technological services, and (iii) the networks of quality systems, middleware and software were also strongly correlated. The correlation between the different networks provides an interesting insight into the multi-dimensional governance of knowledge in sectors and the complexity involved the alignment of interests dispersed among specific communities of practice.

The next chapter provides an in-depth examination of the key multinational companies and their technological partners, showing more details of the organisational configurations emerging in the knowledge network.

7. THE EMERGING CONFIGURATIONS BETWEEN MULTINATIONAL COMPANIES AND THE SECTORAL SYSTEM IN THE BRAZILIAN ICT SECTOR

To understand economic development, one must therefore understand the developmental processes inside firms. If firms are indeed the instruments of development, the study of economic development cannot take place separate form the study of the theory of the growth of the firm. (Teece 2000)

The analysis in chapter 5 shows the crucial position of multinational companies and new private research institutes in the emerging networks in the Brazilian ICT sector. The previous chapter explored some quantitative details of the relationship between knowledge-base in innovation projects and the structures emerging between multinational companies and technological partners. It grouped the project-based networks into three categories - enabling, developing and developed networks according to the organisational boundary and accumulation in the network formed by educational/research institutes. This was followed by an analysis of the pattern of specialisation among different types of governance structures inside the network in each one of the activities and in the patterns of collaboration in different activities.

In this chapter the key nodes of these same networks are examined in greater detail focusing on the underlying organisational configurations emerging between multinational companies and the domestic technological partners in the sector. Based on a combination of qualitative and quantitative data on multiple case studies, this chapter complements the previous analysis focusing on 11 key subsidiaries of multinational companies and their 11 main technological partners in the Brazilian ICT.

The concept of emerging configurations developed in section 3.3 proposes that a limited set of bottom-up organisational *patterns* would emerge in the specific context. These patterns, or configurations, could help to explain emerging properties in the network, predict their future behaviour and explore possible strategies and interventions. The Brazilian ICT Law provides a natural experiment and a valuable source of data to investigate the project-level configurations between institutions, multinational companies and the local innovation system. As pointed out in section 4.2.2, the selection of the cases was based on investments in innovative activities among thoe companies and research institutes involved in the Brazilian tax scheme for promotion of innovation in manufacturing companies in the ICT sector ("ICT Law")[29].

Following the methological procedures described in 4.3.4, the cross comparison among different cases facilitated the development of a taxonomy of usual configurations in innovation projects identifying usual stakeholders in each one of the configurations. On average for each case, three three usual configurations were discussed in detail in each organization interviewed during the field work. The combination of qualitative and quantitative data on multiple case studies led to 12 different configurations in 11 key R&D labs of subsidiaries of multinational companies and their 11 main technological partners in the Brazilian ICT.

The different configurations in innovation projects were distinguished between those usually led by the multinational companies, those led by actors in the sectoral innovation system and those that involved a strong coordination between these internal and external networks. The MNC-centered configurations involve four configurations that are mainly led by the multinational company. The SIS-centered configurations were those four archetypes mainly led by the research and educational institutes in the sectoral innovation system. Finally, the Integrated configurations were those that involve intensive coordinated governance between multinational companies and sectoral innovation system.

Table 19 introduces these organisational configurations in the different categories as they are explored in this chapter.

[29] In collaboration with SEPIN/MCT, this research had access to details of more than 11,000 innovation projects declared in the sector between 1997 and 2003 from which collaborations between multinational companies and technological partners (Brasil 1998, 2003).

Table 19 - Common configurations in different project-based knowledge networks

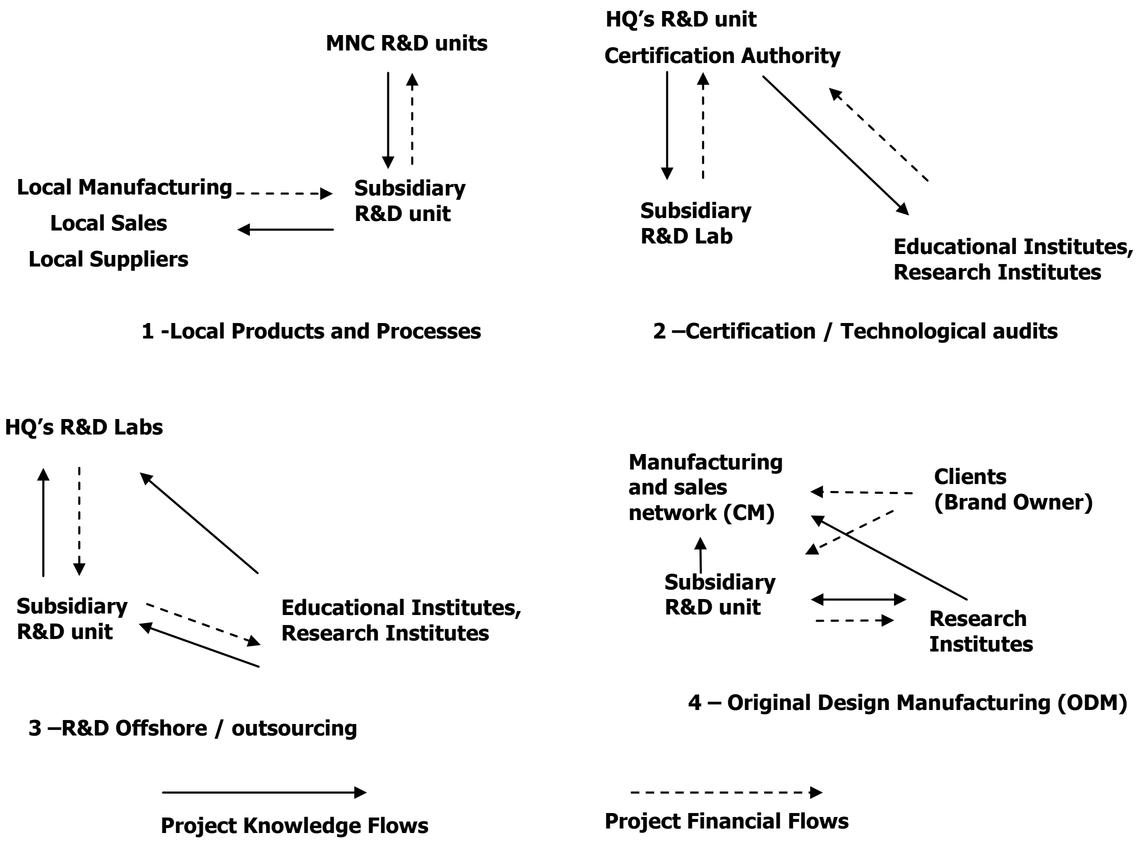
Categories	Description	Common configurations
MNC-centered configurations	Innovation projects mainly organised inside the subsidiary and multinational company	• Local Products/Processes • Certification and technical audits • R&D Offshore unit • Original Design Manufacturer (ODM)
SIS-centered configurations	Innovation projects mainly associated with strong participation of technological partners	• Sponsorship • Technological pools • Structuring/ Priority programmes • Technological Consortia
Integrated configurations	Organisation of Innovation projects with integrating strongly internal and external networks	• Corporate Venture • Global Mandates • Centers of Excellence • Technological scouting

This chapter is organised in order to describe these three groups of configurations identified in the cross-analysis of multiple cases, following procedures discussed in chapter 4. The configurations suggested here (as indeed in any other study of organisational configurations) are not meant to fit precisely into individual organisations. In fact, each individual organisation tends to be involved in a number of configurations and variations between the 12 constructs proposed. This complex structure is illustrated in boxes about the innovation projects in subsidiaries and the technological partners along this chapter.

7.1. MNC-CENTERED CONFIGURATIONS - EXPLOITING THE MULTINATIONAL COMPANY

The first group of configurations refers to organisational patterns emerging mostly from inside the multinational company. The key configurations included in this category are (i) local product/process adaptation, (ii) audit/certification, (iii) R&D offshoring and the (iv) Original Design Manufacturing (ODM) model. These most common connections among partners configurations observed in the developing network are represented in Figure 26. The most common flows of resources (full lines) and flows of knowledge (dashed lines) are also represented in the different configurations.

Figure 26 – MNC-centered configurations



The details of these configurations are presented in this section.

7.1.1. Local products and processes

This was the simplest model of innovative activities developed by subsidiaries. The organisational configuration relating to local product/process referred mainly to stand-alone and autonomous projects targeting specific niches identified by local marketing units or processes needed inside the local operations, including manufacturing units. Most of the time, this comprised adaptive R&D activities, although in some cases, the result was a significant shift from the original design.

The autonomous nature of this configuration was usually considered its main advantage by subsidiary managers. In some cases, these independent projects were even dubbed "submarine projects", as they were beyond the radar of the headquarters. This configuration was also considered a requirement for capacity building as it allowed the subsidiary to explore different technologies and components of the product and process. It allowed the experimentation of the technical group in areas that were considered relevant.

In subsidiaries with limited R&D experience, this configuration was usually a direct result of availability of resources and internal technological opportunities perceived by small technical groups, creating or adapting products relevant to the national/local market at different points in time. However, these initial projects were necessary steps to develop teams.

Despite different levels of technical support from other R&D units inside the corporation, most innovative products and processes developed locally had difficulties in integrating with different departments in the subsidiary. When resources were allocated to R&D uniquely because of regulation requirements, the lack of organisational linkages to the R&D group, even inside the subsidiary, was evident. Resources were very volatile even for the largest groups, making it difficult to sustain the learning curves in these organisations.

The commercial success of many of the local products reported was limited as exemplified by the case in Box 1. At the same time, the same commercial failures showed subsidiaries where systematic interactions with existing clients and/or global strategies were a requirement. Despite the advantages of autonomy, increasing the number of linkages with different elements of the multinational company and sectoral system would be a requirement for achieving successful commercial innovations.

Box 1 - LG subsidiary – Developing local products

LG established manufacturing in Brazil in 1997 and was a relative newcomer to the Brazilian ICT sector. However, given the linked incentives, their R&D expenditure grew from 1.5 million in 1997 to 16 million in 2003 with the expectations of constant growth ahead. Given the incentives, the subsidiary started to develop their technological capabilities. The R&D structure was organised in a functional way. The first group was related to LCD and plasma monitors, and, the second group, in 1999, was related to mobile technologies.

The primary strategy was the improvement of the company's products in the local market. In terms of exploiting R&D activities, there was a strong focus on supporting local sales with adaptation to local markets in demand from specific customers - adapting size, colour, configuration and mobile interoperability. In terms of investments in new knowledge, considerable resources were allocated to the creation of unique technologies. Examples of the interaction with the production in place were adaptations in the CD-ROM unit production and a system for the optical recognition of failures in the manufacturing process and research in raw materials and plastics. However, as the CD-ROM manufacturing was discontinued, the changes developed had a limited life-span in the field. "The internal group was seen as something isolated - engineers that received higher salaries and did not deliver results - we are bridging this gap now".

One of the strategies used was partnerships with different institutions that would already have considerable competence in product development. In a few cases, even shared intellectual property of the outputs was negotiated. The technical performance of products created in the subsidiary were proof of the subsidiary's technical qualification to the multinational network and national clients despite the lack of commercial success in most endeavours. Most independent product development was considered as a necessary learning process that could hardly be accomplished without the specific institutional framework applied to the sector.

7.1.2. Certification and technological audits

Considerable entry barriers and substantial initial investments needed to take place before stronger integration into global network could be accomplished. Different forms of proof are required in order to be acknowledged by key partners, even inside the multinational corporation. Most of the subsidiaries had groups focusing on internal and/or external *certification or internal audits*. The objectives of these activities were twofold. Firstly, certification was important to provide initial qualification to enter into the competition for projects with other units. Secondly, technical audits became a mechanism for learning good practices inside specific technological fields and improving organisational productivity.

In terms of standards, for example, Ericsson's intensely focused on training and improvement of management, design, and coding, and the unit obtained one of the most advanced levels of CMM certification in Brazil and within the worldwide organisation. Many of these processes were transferred to Informat, whose basic operation model was strongly influenced by the routines used in the subsidiary. Their internal project management process was based on the PMI (a standard international certification for project managers) and on the PROPS, the Project Managmeent methodology used by Ericsson. The recent focus had been on achieving CMM level 3 and People CMM. The intense relationship with the main partner strongly influenced the culture and processes of the institute.

In other cases the transfer of routine was less direct. Many institutes used their own mark-up and reinvested in professional qualification. For example, Eldorado had more than 30 internal projects that were financed by the reinvestment of the surplus or by sponsor. However, so far, most of the surplus has been reinvested in the development of professional qualifications in software and project management team. Among the main focus of results, the institute achieved CMM level 3, certified 100 of its engineers in Java, and had an increasing number of PMI certifications.

In addition, the certification was not just provided by independent organisations. Many companies, such as Siemens and Motorola, have strong international auditing systems in order to qualify suppliers to become part of the international R&D network[30]. This resulted in many efforts that prepared some institutes to be qualified inside the global R&D network of the multinational groups, becoming key nodes in the global product development chain.

30 The high ratio of expenditure in travel in the quality-related projects reinforces the importance of international audit exercises to the existing companies.

These qualifications were first developed inside the groups in the subsidiary, and then extended to technological partners (mainly a selected group of private research institutes). However, given the high cost of these initiatives, the certification process was limited to a very small number of key local players. Most of these local players also had to invest themselves on their own qualification and certification process.

There was also an important role for technical excursions inside the corporation. In fact, it seems that a large part of the training in leading edge technologies could not be simply outsourced to local educational institutes. The reason is reflected in declarations collected in the interviews, such as: “it is not clear if interaction with local professors is the best way of learning in new areas. The professors might know as much as we do about the technology, but it is probably easier to call the headquarters at the other side of the world and get some tips that might lead us to a solution much faster”. Therefore, it is important to highlight the importance of professional and on-the-job training executed inside the main companies, especially in new technological areas.

Many interviewees described their initiatives to send teams abroad to be trained and return for the commencement of new technologies. For example, in order to meet new demands in Ericsson, the subsidiary sent a 10-person group to Ireland in 2005 to learn new activities. The subsidiary of Motorola sent a group of 12 people to the US at the end of 1997 in order to learn how to develop a mobile. This group was then expanded locally to 75 people, and it currently has 180 people. “Today, we are going again to the headquarters in order to promote a new learning cycle. We need to reinvent ourselves”. In Lucent, the interaction with the global R&D community was considered to be very strong. There was intense exchange of personnel among units. For example, in order to create the new group, 35 engineers were exchanged for two months.

The subsidiaries also recognize that the balance is dynamic as learning happens in the reverse direction, i.e. from the subsidiary to the other units. For example, the Dell subsidiary in Brazil was the first to outsource software activities from the headquarters in the US. Today the units in India and Russia have absorbed most of its outsourcing procedures. Ericsson Brazil has also moved technology projects to Mexico, training them in some of the operations they have locally. The experiences show that the success of the past does not guarantee the success of the future and renewed efforts have to be in place in order to ‘reinvent’ the subsidiary for the corporation.

These investments in certification and technical excursions usually require a significant amount of time to pay-off, both in terms of subsidiaries and technological partners. Indeed, the patient reinvestment of the profits in internal qualification was noted as one of the main reasons why the private research institutes manage to capture a larger part of the resources inside the system over time. By reinvesting according to the interest of the clients, they could provide better services than those organisations that dispersed their reinvestments in other interests. For instance, in many universities, the profit obtained was coordinated by associations usually controlled by other stakeholders, reinvesting therefore in non-related areas such as their own research projects, academic conferences and educational infra-structure.[31]

7.1.3. Offshoring R&D

Offshore R&D units became an important way to connect the local capabilities with the global R&D network, similar to other cases in different countries (Chen 2002b; Florida 1997; Kotabe 1990). Different strategies were used by subsidiaries to develop these units. Showing some of the early results in terms of local product development was fundamental. Some of them like HP and Siemens, used established internal markets of the multinational company where different units competed by internal projects[32].

Some multinational companies indeed developed strong channels interconnecting with core nodes of the global R&D networks in the area (e.g. mobile handsets, switchers, etc) (see Boxes 2, 3 and 4). Despite the clear loss in autonomy, the connection with the corporation would guarantee resources to the local unit independent of shifts in the regulatory framework. The R&D offshore groups in the subsidiaries were particularly strong in software and middleware innovative activities. Although they compete with groups in other units, some of the local groups have expanded and number up to 500 engineers in these activities.

Resources were used for the development of laboratorial infrastructure inside the subsidiaries defining their position inside the global R&D network (among the top 10 organisations that received investments in infrastructure and equipments, four were subsidiaries). For instance, in 2001, Ericsson inaugurated a 10,000m2 centre which was dedicated to R&D activities and had a local group of up to 600 engineers (see Box 2).

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31 There were also exceptions. INATEL, the first institute that achieved CMM 2 in Brazil, did not absorb its routines directly from the partnerships inside the Law. The partnerships with companies provided resources to diversify to other areas and, although companies have no influence on the administrative board of the institute, the board (mainly composed of internal members and local associations) has focused on the use of resources in the development of the centre. In terms of the development of internal competences, the centre in SRS contracts mostly people from the institute.

32 Sometimes the Brazilian subsidiary created this type of organisation inside the main organisation that later was expanded to other units, as in the case of Dell.

Box 2 - Ericsson - "Those that brought us here will not take us forward[33]"

The subsidiary of Swedish Ericsson in Brazil has a long history of technological capabilities. Founded in 1924, the subsidiary developed technological capabilities in hardware in the 70s and started development of middleware in the 80s, followed more recently by software..

Since the regulation, the growth in the R&D activities at the subsidiary level has been substantial. With the shift in the market from telecom infrastructure to mobile, the tax incentives have considerably reduced since then. The internal organisation is in a matrix, where they receive demands from business units worldwide. This local group increased up to 600 engineers during the internet bubble. However, just after the inauguration of a new 10,000m2 R&D laboratory, the subsidiary faced a shutdown risk at the end of 2001 and during 2002. Similar to other competitors in the sector, the consolidation affected the entire group. As a result of the worldwide reorganisation, the activities in Brazil were reduced to 250 employees in 2005.

In 2005, the subsidiary of the Swedish multinational company received 100% of the internal R&D activities at the subsidiary from international demands. The company invested twice the amount required by the Law in internal investments. However the investments required inside the Law were only enough to keep the price competitive with India and China, as the engineers in Brazil were twice as expensive. In fact, the sustainability of the Brazilian site is, in great part, related to the required investments inside the Law.

The subsidiary faced the threat that the product line would be discontinued in no more than three years from the moment of the interview, even that the discontinuity could happen during the next year, posing a threat to the sustainability of the group. Recently, a Finnish manager was assigned as director of the R&D activities at the subsidiary in an attempt to promote linkages between the subsidiary and the worldwide organisation and to devise ways that the subsidiary could contribute to worldwide Ericsson operations.

Some of the units became trapped in the need to offset their participation in the global R&D network and received little compensation for the activities developed for the corporation. In hardware and semiconductors, however, subsidiaries faced limited scope for growth inside the intra multinational network given the strong competition with East Asian and Chinese subsidiaries. In these technological areas, local subsidiaries such as Siemens and Ericson had to downsize teams as did other subsidiaries after the burst of the Internet bubble. As Asia specialised more and more in these activities inside the corporation, even in products for the local market, components related to semiconductors and hardware were systemically outsourced from the local subsidiary to R&D units in Asia.

For instance, the subsidiary of Siemens in Brazil reached a position as one of the three largest R&D units inside the fixed telecom infra-structure offshoring large hardware-related projects (see Box 4). Alone, the subsidiary conducted more than 68 projects related to hardware between 1997 and 2003. However, Siemens Brazil was not able to sustain its team in hardware as a result of international competition with other units and consolidation after the end of the internet bubble. A similar position in the corporation was

[33] Citation of Ericsson's CEO in Ericsson subsidiary's presentation (MCT,2006)

achieved by NEC, followed by an even stronger decline. The team was first outsourced to Celestica and later, it was dismantled completely.

Box 3 -Nortel – A R&D off-shoring unit

The company entered the Brazilian market in 1997. Before that, it was represented in Brazil by PROMON. In 1998, they started to develop TDMA software for the corporate portfolio. There were also a considerable number of adaptations required by the local market. The number of employees in R&D has been stable with around 150 employees during the last three years. In 2005, 90% of the R&D activities were for global demands in software. The technological focus has moved from the TDMA to CDMA network management involved in large releases inside global projects (at the moment, they are involved in release 15 while the product available on the market is the release 13). The unit attracted twice the amount required by their obligations in intra-firm corporate R&D demands. In 2001, they developed initiatives in Radio Frequency Engineering Service and in 2004 they worked on the conception of an algorithm for RF distribution for AT&T Wireless in the US - This algorithm was a fundamental part of Radio Frequency distribution related to the TDMA/CDMA transition. However, this was a one-off project.

The unit in Brazil responds primarily to the mobile phone division worldwide. i.e. directly to the R&D director in Ottawa, Canada. In contrast, their relation with the local subsidiary is a 'dotted line'. The R&D unit has, therefore, very little interaction with local marketing and manufacturing. The marketing units are connected with LC's (Leadership category), while the R&D is connected to global PLMs (product line managers). Although the subsidiary admits that there could be more and they would like to see more dynamism in the local market, the structure of the multinational company established different channels of communication for local marketing units and R&D units to divisions abroad. Recently, just 10% of its activities were related to adaptation to local customers. These developments tended to remain ad-hoc demands from the local sales area.

In contrast, the international interaction was very intense, not just in relation to the interaction inside projects, but also in the exchange of human resources. The unit found its niche as having quality comparable with units in US and Canada, and prices comparable to China and India. However, they were not necessarily in a secure situation as their costs were higher than the competing units for projects. At that moment, the projects in India were mainly subcontracted to local companies, and they did not have the same quality standards. However, there were similar teams in China that were expanding rapidly. One of the interviewees argued that the unit would need to have more investments to triplicate its team, and therefore, provide competitive costs comparable with India and China.

The dynamic with technological partners was particularly striking. The Northern subsidiary is located in the Campinas region, a quarter mile from the CPqD centre (previously largest R&D centre within the state company). The CPqD, one of the owners of Promon, was an important partner at the beginning, but throughout the years the connection with CPqD diminished and there are no project in existence at the moment with the co-located institution. The company developed sporadic projects with Brisa, IPDE and UnB. However, the main partner was Inatel, originally an institution from outside the region, located in a small city in the south of Minas Gerais, Santa Rita do Sapucaí. Different from CPqD, Inatel was flexible in attending to the MNC requirements such as co-location of employees inside Nortel's lab and direct coordination of the personnel by the subsidiary project managers. In recent years, an increasing proportion of the total activities were subcontracted to Inatel giving cost pressures .In 2005, Inatel already corresponded to 65% of the employees working inside Nortel R&D lab.

Box 4 -Siemens - Competing globally, reorganising locally

Siemens Mercosur is the largest firm in the sample, having more than one hundred years of presence in Brazil. The subsidiary has developed their technological capabilities mainly inside the telecommunications area[34]. The group is one of the larger of the investors in R&D inside the legal framework of the Brazilian ICT Law, leading in investments in hardware and middleware. With so many different groups and products, the challenge became the creation of a local portfolio of innovation, projects that would guarantee the sustainability of the groups in Brazil. At the moment of the interview, the R&D teams at the subsidiary were divided in six groups. The traditional groups were located mainly in Curitiba – south Brazil, with partnerships in different regions. This group had its origins during the closed market when the subsidiary interacted closely with CPqD inside the Telebras groups to develop digital radios, transmultiplexs and other items that should be created using national technology. Throughout the decades the subsidiary faced a considerable number of technological trajectories, going through a series of technologies where large R&D teams have emerged, developed and phased out. The existing large groups are mature, receiving the largest share of the projects from units at the headquarters. The units are named Carriers (Telecom Switchers) with 60-70, and Enterprise, with approximately 100 engineers. The group responsible for Networks has decreased recently to 120 engineers. There are also small adaptation groups such as Wired Handsets and Mobile Core. After the decline in the telecommunications market related to infrastructure, the tax incentives have reduced significantly. To sustain its operations in 2005, the subsidiary spent more than twice the required by the legislation. The group also started operating in the emerging market of mobile handsets. The mobile handset manufacturing unit is located in Manaus, a region that has specific incentives and requirements of manufacturing and R&D activities inside a specific free trade zone. The group that specialised in Mobile Handsets started in 2001 and is composed of 300 people with the expectation of growth of up to 800 people in three years supplying mainly global markets. In general, Siemens' subsidiary in Brazil benefited from a worldwide migration to low cost centres, where the units could become development units and centres of competence. Throughout the recent decades, the subsidiary in fact, acquired many responsibilities inside the corporation. For instance, the global attributions were fundamental to guarantee the R&D unit survival during oscillations in the local market. The creation of successful products that contributed to the whole organisation increased the status of the local managers.

[34] Although outside the scope of the incentives, the technology management at corporate level is quite remarkable. Also, the subsidiary has had, since 1998, a corporate department to support initiatives across the different areas in Siemens (in Brazil, these areas are telecommunications, industry, energy, medical equipment and business solutions) and interaction with local partners. The director of this area is also the director of ANPEI, national association of innovative enterprises.

However, the increasing proportion of activities in the R&D market inside the multinational network also meant strong competition between subsidiaries. The R&D management of the main products remained strongly coordinated at the headquarters. Usually, a project manager in Germany divided each large project into smaller packages and distributed them around the world. Similar competences were created in other subsidiaries forcing constant improvements in costs and competition among units for participation in new products. This competition was not only based on price and quality. Strategic and political questions were fundamental. Given the increasing bargaining power inside the organisation, the natural trend was to send activities to China and India,. The competition with Eastern Europe and Russia was also strong and the unit lost activities to these regions. There is a constant struggle for projects inside the corporation, especially during the considerable recent downsizing facing the group worldwide.

There was an additional challenge derived from the institutional and market changes, and resulting in changes in the R&D obligations. The recent changes encouraged the reallocation of the activities previously established in the South towards other regions where the company had increasing investment requirements. Duringrecent years, the company had to sponsor a strong migration of personnel and activities to the Northeast and Manaus. It naturally involved profound sacrifices in terms of productivity for the company, as well as considerable distress for relocating groups and employees. Facing the recent impact of the legislation on the R&D activities, the company was keen to cooperate with other companies in the sector and to develop its channels of dialogue with the government in order to discuss the regulation and to improve existing legislation in the sector. One of the Siemens directors was the president of the Brazilian Association of Innovative Companies (ANPEI) and the company contributed to the formation of the R&D group inside ABINEE, where the competitor firms in the market established periodic meetings in order to debate and present proposals to the government.

The cultural and organisational idiosyncrasies of each multinational company played a crucial role. As shown in the case of the Brazilian subsidiary of Lucent (box 5), some of the markets for offshoring R&D projects concentrated considerable bargaining power on headquarters, as many units fiercely competed for projects. Others were characterised by more benevolent participation of the headquarters or even decentralised supply and demand among units. The behaviour of the internal market for offshore activities in specific divisions of the large multinational companies became the core limitation for the success and failure of these activities.

Box 5 - Lucent - Organising to compete in the multinational internal market for R&D (I)

Two groups that were not directly connected to the acquired companies were created inside the subsidiary of Lucent in Campinas. The first group, related to convergence, was established in 2000 and was integrated with Lucent global teams. This group had a fast growth rate, but, responding to worldwide consolidation, this group had also decreased considerably, from more than 200 employees to about 40 engineers in recent years. A second group was created in 2004 in order to develop competences in optical access (n-midia), in particular, an optical concentrator for public commutation networks. This group has now around 50 engineers. The substantial reduction in the importance of the products under incentives in relation to the total sales of the subsidiary put considerable pressure under the sustainability of the R&D activities at the subsidiary.

Internally, the company just maintained a small in-house team composed of nine people, four of which were technical managers and five were administrative support. The internal managers were primarily nodes of a matrix-form structure, mainly connected to global Bell Labs and internal units of the subsidiary. Their main responsibility was to forward the requirements of the projects to the teams in partner institutions that were responsible for all the operational R&D projects.

In order to sustain the activities at the subsidiary, there were constant incursions in other units abroad to obtain new projects and responsibilities. However, the break in the existing internal organisation proved to be a difficult process. For instance, during the past year, there was an attempt inside the wireless group. However, as argued by the interviewees, the cohesion inside the American group was too strong and the conversations ended in nothing concrete. Although there is an understanding about what is a centre of excellence, there is no such term used internally, as most of the labs remain in the US

In 2005, the portfolio of projects in R&D had no connection with the local production and the interaction with the local market was also limited. There was limited interest from the local sales units in selling new ideas or products developed at the subsidiary, as their sales targets were connected with the company's main product lines. In fact, many products developed at the subsidiary were never sold in Brazil. For example, some functionalities of the IP Centrex that were developed locally, have always been supplied as a bonus in the Brazilian market while in other countries, it was a charged service. Some R&D projects managers tried to generate demand from local clients in order to create more opportunities and to capture the attention of sales units. However, these were sporadic situations and the distance from leading clients was a strong threat to current capabilities.

The international competition with India and China for outsourcing is also quite striking. Despite the important group of Indians inside the Bell Labs, today the subsidiary in Brazil is managing to compete for projects with the Indians in both price and quality. However, Chinese engineers are still much cheaper. The pressure has been on the improvement of the project management layer in order to improve responsiveness to time, cost and quality pressures.

7.1.4. Original Design Manufacturer (ODM)

The model Original Design Manufacturer (*ODM)*[35] configuration, usually associated with ICT companies in East Asia (Hobday 1995; Hobday2000b), has also been found in contract manufacturers (CM) in Brazil. Traditionally, it was assumed by different CMs that the creation of an R&D network overlapping the CM network would result in

[35] An original design manufacturer (ODM) is a company which manufactures a product which ultimately will be branded by another firm for sale.

conflicting interests for their clients. However, the panorama in the industry has been changing. Although most multionational CMs traditionally do not have R&D groups, some CM companies are increasing engaged in providing ‘design services’ for clients.

Some subsidiaries in Brazil started to operate in an ODM configuration with the growing outsourcing of the production activities in the sector. Taking advantage of the tax incentives, some contract manufacturing units offset the costs of R&D to possible clients, providing widespread R&D services to brand owners. Contract manufacturers as Solectron (Box 6) and Flextronics created their own infrastructure to provide R&D services, representing a passage of the second tier multinational suppliers in Brazil following an OEM-ODM path. Contract manufacturers have used the resources to provide product development services for other possible clients, usually other companies with a stronger brand yet no focus on product development. Generic products such as ATMs, mobile handsets and ADSL modems were developed internally by subsidiaries or in partnership with local partners and then commercialised with the brand of banks, telecom operators and internet providers.

In some cases, these R&D labs in Brazil were among the first inside the global contract manufacturing network. Therefore, in general, the subsidiary activities in innovation tended to be completely stand-alone - especially local product developments - as there were no systematised R&D groups inside the multinational CM. As more and more R&D groups are created inside the CM network, CMs in Brazil are also starting to attend to ODM global demands.

Box 6 -Is there a place for a traditional OEM-ODM strategy? The Solectron case

In 1997, Solectron was a spin-off of Ericsson in Brazil. The unit is located in Jaguariuna, in outskirts of Campinas and it has become one of the most important CM's in the Brazilian market. In 2002, it started to provide R&D services for prospective clients by partially making use of their acquired obligations. The subsidiary divided its internal competences following the local market division: IT Products and Telecom products.

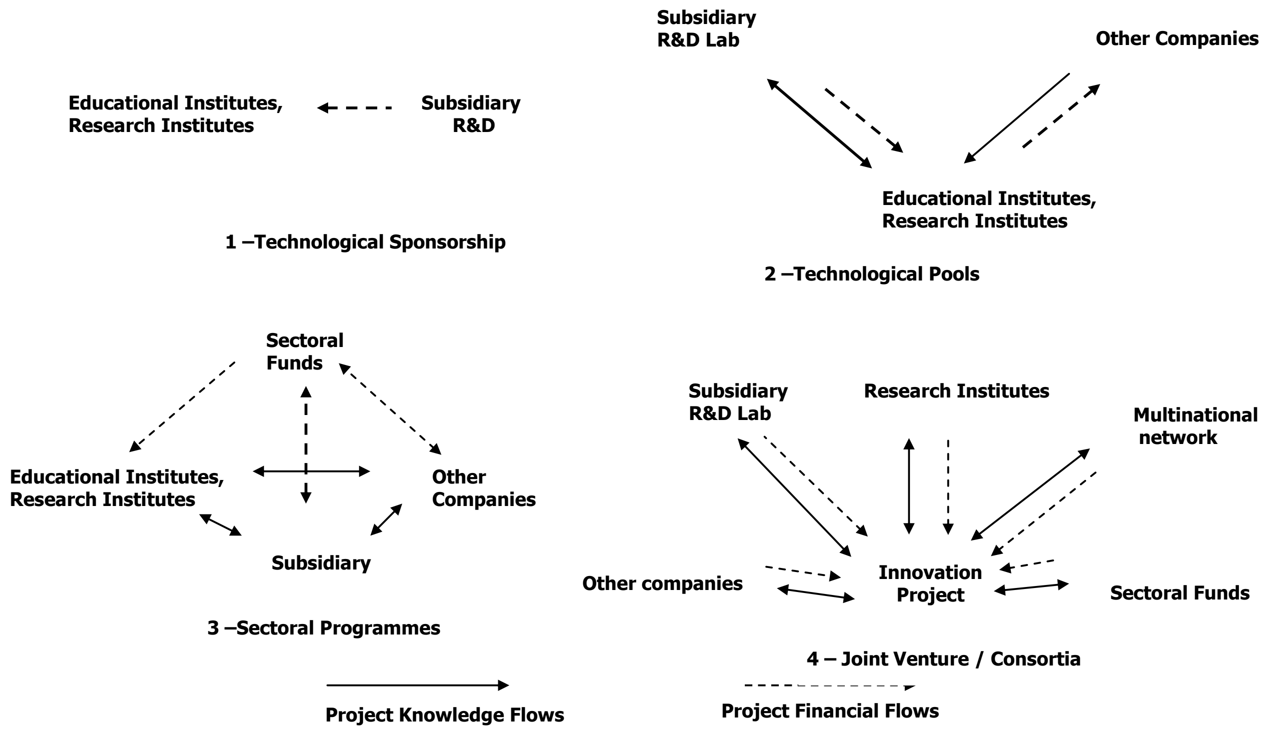
It was a significant change from the earlier strategy. The unit had operated by mainly providing an unstructured venture capital to innovation projects in institutes and universities (CPqD was one of the largest receptors). However, the subsidiary decided to develop a stronger internal R&D team and the department was formally created in 2002. The logic was the development of new products as a complementary service in order to attract the rights to manufacture the equipment. The clients proposed the project to be developed to Solectron and the company became responsible for the manufacturing and for the R&D obligations of their clients. "Many of the companies have no interest in R&D activities and they propose them us to absorb all their obligations". The focus has been on improving the efficiency of the interaction between collaborative design with companies that have a clear brand and client, their manufacturing middleware (e.g. through 6 Sigma methodology) and the management of R&D activities that comply with the government requirements, in terms of legal support and integration.

It is important to note that the subsidiary completely changed its focus from interaction with clients to interaction with sources of technology. As argued, this was reinforced given unsuccessful experiences (relative low sales) when the product developed did not have a clear customer and market. To quote one interviewee, their motto has been "no product deriving from engineers' imagination". The company developed a clear strategy to operate both as OEM and ODM. Some of their main projects recently have been on products commercialised with other companies' brands (e.g. an ADSL modem had 'Terra' 's brand - one large Internet Provider in Brazil, ATM-units with the Bradesco, Telefonica and Banco do Brasil name and a low-cost PC sold as Magazine Luiza - a large retailer in Brazil). The most recent and main product has been a two-year development of a generic mobile handset.

7.2. THE SECTORAL INNOVATION SYSTEM CENTERED CONFIGURATIONS

SIS-centered configurations refer to the organisational arrangements where host-country technological institutes such as research institutes, universities and sectoral agencies have a prominent coordination role even when funded by subsidiaries of multinational companies. These are usually associated with initiatives that aim to develop 'public goods' that would benefit the different actors in the sector. Four usual configurations were observed under this category: sponsorship, resource sharing, structuring programmes and technological consortia. The most common knowledge and monetary flows in these different configurations are summarised in Figure 27 followed by a more detailed discussion.

Figure 27 - SIS-centered configurations – interacting with the host innovation system



7.2.1. Technological sponsorship

The first simplest configuration identified is Technological *Sponsorship* of local partners, particularly groups in local universities and research institutes. In some cases, subsidiaries offered resources without any substantial expected return, other than a certain level of recognition of the sponsorship. Decisions were based on historical or geographic proximity, social relations or general area of affinity. Although there were usually some results that could be absorbed by the firm at the end of the project, this was usually indirect and accidental. Some of the examples are technical seminars and conferences, new training and disciplines in the local university and research capabilities.

Sponsorship of training was particularly important in qualifying personnel according to company demands where employees took part in courses in educational institutions. The innovation projects also supported the creation of new courses which resulted in a decentralised improvement in smaller universities and educational institutes. This resource sharing was not adopted so effectively by the traditional centres of excellence in Brazil. In fact, as argued by one leading university: “smaller universities were more agile in creating and adapting courses to attend to the company needs” (Unicamp). Many educational organisations, (many connected to professional education), created and improved their routines as required to quickly create and adapt courses according to the demand of local companies where the investments through the ICT Law that still remained an important part of the revenues. The ICT Law became an important part of the economic feasibility of post-graduate courses that could then be opened to the entire community (CEFET-PR).

There was also sponsorship of different academic groups. During the early moments of a specific technology, most companies recognized the requirement of partnerships that needed to be divided within groups in the university and existing centres. During this initial period, it became an important resource to experimentation and learning in the sector, establishing research groups in many related areas. Some of the technologies developed resulted in synergic investments with other companies and some research groups were maintained. However, this was certainly not the general rules as many cases individual companies could not sponsor all the investments required. Furukawa, for instance, supported research in Radio-Frequency and Optics as their main area of interest related to optical cables. However few other companies invested in similar technologies and the sectoral capabilities in this area still remain in their infancy.

In addition, the resources available to academic-led initiatives tended to decrease over time. As companies established their own groups, the strategic importance of their own projects in product development increased in the organisation. Subsequently, product development within the global R&D structure and with established product development partners also increased. As the institutes specialising in "product development" became mature, the slack available for exploratory research decreased, and new institutes dragged the resources away from risky ventures.

In particular, the resources for academic research in the south and southeast region were reduced sharply with the change in the regulation. The regulation requirements for diversifying the partnerships in different regions resulted in the collapse of sponsorships in the South, as these had to compete with established partners in established product development activities.

Certainly it also resulted in new opportunities outside the region as the change in the regulation intended. During the last period there were a larger number of collaborations in research with universities outside the subsidiary location. The interviews reinforce the previous findings that there was a strong decrease in the number and intensity of the links between the south/southeast states contrasting with the large expansion of the linkages with the central-west and northeast region. However, similarly to what happened in the South, the "sponsorship" provided by the established companies for academics was also retracted as some private research institutes matured. In addition, this process accelerated as established institutes in the South/Southeast created their own back-offices in the other region or established partnerships with smaller institutes in the other region.

Naturally, different forms of recognition could be expected. However, in most cases, these were simply a result of the accumulation of specific capabilities of the technological partner or general benefits for the community. In general, firms were not willing to commit large amounts of resources to these sponsorship activities. These projects lacked economic returns and results in possible benefits to competitors therefore making them sporadic by nature. In some cases, when the creation of teams, laboratories and equipments was sponsored, there might have been subsequent problems of economic sustainability given long term fixed costs.

These practices were also an important part of the "public relations" of the multinational companies in front of the specialised community. In some technical communities, subsidiary managers faced strong techno-nationalism. Indeed, a large number of individuals, groups and organisations received substantial benefits from this type of broad sponsorship of specific projects. In addition, sponsorship allowed multinational companies to check affinity and value of partners. Most of the other enabling networks tended to evolve from sponsorship relations between individual companies and technological partners.

7.2.2. Technological Supplier Development

The availability of resources such as qualified engineers, technological services and laboratory facilities and research talent is considered a fundamental element for the dynamic of local and regional innovation systems (Marshall 1898). These resources are usually considered an important component for the re-location of innovative activities between units of the multinational companies (Cantwell & Iammarino 2003; Cantwell & Janne 1999), but these shared resources can also be formed during interaction with multinational companies.

Some of the relations between multinational companies and technological partners evolved into more stable configurations called here *technological supplier development*. In this configuration, the initial allocation of resources resulted in the formation of useful capabilities in technological partners that could be then utilized by the original sponsors as well as other companies. These capabilities were mainly developed in terms of infrastructure, training and provision of human resources, services of test equipment and research.

New actors emerged in the sectoral system of technological institutes vis-à-vis established organisations. In many cases, smaller organisations had a larger flexibility to accommodate specific needs of individual companies, such as tailored post-graduate programmes and adjustments in the corporate governance of recently developed infrastructure and personnel, despite their relative disadvantage in terms of technological capabilities.

Relatively few institutes saw the possible investments as a clear chance to grow. Institutes such as the Eldorado (Box 8) and Informat (Box 7) developed very quickly by partnering with Motorola and Ericsson respectively. As they had a relatively small internal organisation or they were in a formation period, strong organisation resistance did not restrict the type of preferential treatment that could be agreed upon with the sponsor company. In practical terms it meant that the company-institute relationship could be supported by other formal and informal joint-governance mechanisms.

Box 7 - Informat Institute or Ericsson's Institute?

The Informat Institute was created in 1995 and has been the single largest receiver of investments inside the Brazilian ICT Law. A direct result of a spin-off of a team of 160 employees of the Ericsson subsidiary in 1996, the institute is located in the Ericsson technological park in Jaguariúna, on the outskirts of Campinas. Following strong demand by the main partner and companies connected to the Ericsson group, the institute had a strong growth until 2000/2001. At this point, they were more than 400 engineers working in R&D. 90% of them were involved with projects for Ericsson worldwide. This number decreased to almost 200 employees in 2004, following a large decrease in the demand from the main client.

Although the institute also developed projects for other local subsidiaries and national companies such as Sony (that has a worldwide joint-venture in the mobile business with Ericsson), Toledo and DIMES (these companies were also part of the Ericsson group in Brazil), for many years, the institute was relatively closed to the external market, given the growing demand from the worldwide Ericsson group. Moreover, Ericsson and other companies of the Ericsson group had permanent seats on the administration board of the institute and exercised a strong influence in its managerial direction. In fact, the interrelation between the institute and the multinational led to interventions from the regulatory agency (SEPIN), discussing matters related to the board organisation and operational practices such as the co-location of teams. The recent decrease in the level of activities demanded by the main partners and the consequent difficulties in the sustainability of the internal groups created pressure for large organisational changes in relation to the partners.

Half of the internal activities of Ericsson's subsidiary are outsourced to a close technological partner - Informat - that is located in the Ericsson area. Informat - a spin-off of Ericsson - become the largest receptor of investments inside the ICT Law, mainly given the strong interaction with Ericsson. This partnership provided the subsidiary with enough well qualified human resources that were trained and treated largely as internal employees.

Recently, the organisational changes in the institute towards openness have gained momentum. Throughout this period, and in response to fluctuations, the partner has become more independent, sharing its resources with other companies. There has been a considerable change in the institute's corporate governance where sharing responsibilities are better accepted from both sites. "The changes we are promoting now should have been done a long time ago. We were trapped in a short-sighted organisational perspective". Some months after the interview, the institute was renamed "Venturus", reinforcing the new phase in its development.

Box 8 - The Eldorado Institute or Motorola's Institute?

The Eldorado Institute was created in 1999 and emerge to become one of the most important research institutes in the ICT sector. In just a few years, it grew to have more than 300 employees in innovation activities. It was initially responsible for coordinating initiatives sponsored by companies such as improvements in the curricula of universities and shared infra-structure of test and technical personnel among companies. Motorola has played a fundamental role, initially subcontracting many of its projects to the institute and becoming part of its administration board.

However, the institute is not a direct spin-off of Motorola as, from the beginning and through the years, it has not been formed by their employees and it has kept an open approach regarding the association of new members and action in the market. Already in 2000, Celestica and HP had become important clients for the institute and, at the moment, there are at least six strong partnerships developed inside the Law (although the projects with Motorola still represent the largest part of its revenue).

They have developed strength by being flexibility in attending to different customer needs. The institute is constituted as an association with the administration board comprised mostly of the companies that use the institute. The administration board is responsible for controlling general information and approving general strategy in terms of re-investments.

The existing regulation prevents the distribution of the dividends to the associate members and also prohibits any salary or benefits for the board of directors. Therefore, the participation on the board has been completely and unavoidably voluntarily. Companies that interact with the institute are invited to become associate members of the institute, and, if elected, to take part in the board. Motorola remains one of the members of the board, but many other companies associated with the company also share the top-level decision making process. Some new partners, the most important being HP, have avoided entering into the board administration based on an internal policy, despite the invitations on behalf of the institute. According to HP, this could result in an unhealthy pre-selection of a technology supplier, rather than fairer competition with many possible suppliers.

However, for the institute, the development of the board was an important way to expand trust with clients and to expand the number of projects outsourced to the institute. The development of efficient corporate governance would aim to guarantee the connection of the institute within different models that can be experimented with new members maximising institutional flexibility.

The importance of the ICT Law in the formation of the institute could not be overstated. In 2005, more than 85% of the institute revenues still came from partnerships inside the Brazilian ICT Law. At the same time, although the ICT Law was a requirement during the formation, the recent plans are for diversification and expansion in the open market. Probably the most important pressure comes from the uncertainty related to the institutional framework: “it is worrying…it can disappear with a pen”. Additionally, the growth inside the regulatory framework may have reached its limits. The institute, therefore, expects to diversify its sources of income to other companies not involved in the institutional framework.

Most of the multinational companies developed long-term associations with private research institutes. Meanwhile, these institutes, first involved in other technologies, diversified their clients in software projects becoming key nodes in the integration and recombination of capabilities in the sectoral network though there has been considerable organisational development. In relation to the internal organisation, concurrently, following changes in the demand, most of the institutes accumulated teams that could supply different clients.

In parallel, reinvesting the returns of the projects inside the ICT Law in process improvement and professional qualification, the research institutes started to develop their own teams. Rather than academics and researchers, the teams were formed mainly of full-time engineers, becoming important sources of capabilities for new and old companies that were not willing or able to have high initial investments. In general, by focusing on professional qualification, these institutes sustained very competitive teams in terms of price and quality ratios while at the same time, they were protected from direct competition from private firms that were not entitled to the same benefits.

In order to maintain a low overhead, these private research institutes generally operated as project-based organisations. For the clients, it allowed the appropriate accomodation of their intellectual property requirements and the different models. For the institutes, it allowed the diversification in scope to areas with less conflict with the original clients. However, this also resulted in some cavets.

Private research institutes operated as project-based organisations, and in this sense, the transfer and diffusion of knowledge among groups and different partners are by no means natural. Some institutes, like INATEL (Box 9), created groups in firm-specific technology resulting in relatively isolated groups. In many cases, the institutes' engineers were co-located with the client's R&D group. working as any other of the client's engineers.

The client exercised considerable influence on the processes and culture of the group and "they are more like them than us" according to a private research institute manager. Co-located groups within the clients' group used to face "identity crises". The underlined reality is that institutes which provide human resources that are controlled by different companies are not enough to fulfil the expectations of any systemic knowledge flow.

Box 9 – INATEL – Finding the synergy between software outsourcing and a hardware cluster

The Inatel was created in 1965 in the South of Minas Gerais, in a small city with 35,000 inhabitants called Santa Rita do Sapucaí. Despite its name which suggests a link with the federal government, the institute is a private foundation, offering one of the pioneering undergraduate and postgraduate courses in telecommunications. Today, the institute divides its income equally between the graduate and postgraduate courses and the activities with companies concentrated in the Inatel Competence Centre. Related to the latter, approximately 95% of each deals with the ICT law.

The institute is located in a region known for its large number of relatively small hardware-based firms (more than 100 in total). Nevertheless, the R&D projects of the institute have been mostly connected to companies outside the region, mainly in Campinas.

The origin of the R&D projects inside the institute started in 1989 in cooperation with IBM. In 1991, after some unsuccessful trials with professors, the institute began to contract full-time engineers to work in Campinas for this partnership. These groups grew and, eventually, shut down after IBM closed its R&D activities in Brazil in the mid-1990s.

The previous group was dispersed throughout other organisations, and, in subsequent years, ex-members of IBM projects were the originaters of other projects at the institute. In 1997, the institute started projects with NEC, and, in 1998, with Nortel and more recently, some projects with Motorola. Subsequently, NEC also closed its R&D activities in Brazil. Although it created a threat for the institute, this was overcome by the growth of the cooperative projects with Nortel. They currently have 80 people co-located in Campinas with its projects within Nortel.

The partnerships with companies provided resources to diversify to other areas. In relation to the courses provided by the institute, there were improvements in the strong traditional courses in electronics and telecommunication, as the Computer Engineering course was 'inspired' by the partnership with Nortel. In 2001, the institute created installations for the Competence Centre in SRS - MG. The center in SRS contracted mostly graduates from the institute. In 2005, the centre had 45 people in its unit in South Minas.

The institute was also the first one to be certified as CMM level 2 although the required CMM processes developed were isolated from the other group that worked in partnership with Nortel. The institute became a provider of R&D activities for a large number of relatively small local companies, such as Leucotron, Batik, Benchmark and FIC (a Chinese motherboard manufacturer installed in the region). The institute also benefited from venture capital investments of a CM local manufacturing contract that provided resources to internal ideas of the institute.

The institute also tried to share risk and investment in products. However, they withdrew from this strategy after some unsuccessful results. The institute 'understood that we do not have the perception of the market to make these investments', therefore, the focus has been shifted to developing partner companies in the commercial area in order to attract more projects to the institute.

The institute has also attempted some internationalisation. The first initiative inside the unit in SRS was based on interaction with local companies. Articulated by a local company, they interacted constantly with manufacturing units in the US and abroad. Recently they also ventured into a consortium of software exporting companies, taking part in business rounds and conferences. However, this strategy has thus far shown limited results.

In many cases, the original companies had a privileged seat on the board of the partner institution (in some cases, even defined in the statute)[36]. Among these new private research

[36] In fact, most of these private research institutes have a larger proportion of companies in its administrative board in comparison with other governmental or educational institutions showing

institutes, many of them remain highly connected with the original sponsors. For the institutes, this sponsorship was fundamental for their initial growth at the time that it represented a challenge for their diversification. Other companies in the sector did not feel comfortable in entering in partnership with an “institute of a competitor’s company”.

There were also important differences in the way the original sponsoring company enforced its influence on the partner. While some institutes showed diversification in the number of clients from the early days, other subsidiaries suffered from changes in the global demand of the main partner and just recently “allowed” the partner to developed more autonomy and share resources with other companies. An extreme example of the unhealthy dependency of the institute with the main client was identified in the CPDIA case, where the closure of the R&D activities in the subsidiary of the Japanese company NEC directly resulted in the insolvency of the institute.

Some generalisations in recent studies, such as the idea that the MNC’s created ‘captive’ research institutes, do not necessarily hold for the majority of the multinational companies. Although these relatively new institutes remain highly connected with the original sponsors, the institutes and companies are increasingly networked among themselves. There is a larger level of cross investments among partners in pooling together resources and allowing greater autonomy of the partner, in order to sustain its structure during fluctuations in demand.

7.2.3. Sectoral Programmes

Sectoral Programmes had an important role in structuring and prioritising initiatives (Garcia & Roselino 2002; Stefanuto 2004b; Tigre et al 2001). Although the leadership of the government varied over time, new institutional mechanisms emerged during the period in order to strengthening these forms of collaboration. In the beginning of the period, there were also many companies sponsoring specific sectoral policies.

The two largest ones were the RNP (National Research Network), whose aim was the development of a national backbone for internet inside the universities and institutes with 80% of funds coming from the ICT Law (MCT 1995), and the SINAPAD, a national system of high-performance computation, creating disperse provision of supercomputer services. More recently, structuring programmes, mainly sponsored by the sectoral fund,

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that many of them can be well characterised as business associations. More details about their governance in the other trajectories.

finally operational in 2003, also became a new source of funding. For instance, a recent call favoured the modernisation of the infrastructure of research institutes[37].

An important number of the sectoral programmes were led by CPqD, previously the technological centre of Embratel – the state company. During decades of import substitution policies, CPqD was important in the development of national technology, as introduced in section 5.1. During the liberalisation process, CPqD (Box 11) was transformed into a private foundation, while still receiving a substantial part of its resources from the federal government and maintaining a board mainly comprised of personel indicated by the government.

At the same time, some subsidiaries were openly involved in the support of government-led structuring programmes from the beginning. In fact, programs such as the National Research Network (RNP) were mostly sponsored by individual companies. Others, such as the Softex - initiative - that aimed to promote the exports in software - did not manage to attract the expected investments from companies. In part, subsidiaries (main possible sponsors) started to reallocate resources to other priorities and shifted away from the government agenda. For, instance, multinational companies had little direct interest in promoting domestic firms' software exports programs.

Some multinational companies have also attempted to develop wide reaching changes in the curricula of universities. The most important initiative was conducted by Motorola (alone it corresponded to 32% of the total investments in the training category during the entire period). The initiative, coordinated in partnership with the Eldorado Institute, became a programme to improve and update the main Engineering and Computer Science undergraduate courses throughout Brazil (see Box 10). In fact, this type of coordination had a widespread benefit for the system, qualifying more personnel than the company could actually absorb.

37 Modernização da Infra-estrutura dos Institutos de Pesquisa Tecnológica, Programa Nacional de Incubadoras - PNI

Box 10 -Motorola – Leading a National programme for university curricula improvement

In the early years, Motorola had a leading role in targeting the development of human resources through a national programme called PCT (Technological Training Programme). In 1998, the unit created an internal group responsible for "university management". The subsidiary started a partnership with 15 universities in order to improve the undergraduate courses in engineering and computer sciences. The early activities were mainly the inclusion of optional courses, such as quality in software, not available at most of the universities. The initial activities showed that this was not an easy task and proposed adjustments to the courses faced strong organisational inertia. Frequently, the company had to push against strong resistance from the universities that considered their influence undesirable.

Already in 1999, the coordination of the programme was outsourced to the recently created Eldorado Institute. Throughout the programme, the company developed preferential partnerships with some universities - according to the company - especially interested in adapting themselves. Among them, UFPE and USP- São Carlos were selected by the company to start a software residence program. Some of the recently trained people were absorbed by the company demands. However, the subsidiary was not able to hire as many graduates as they expected since the end of the training coincided with the end of the internet bubble. Despite the unexpected event, newly created institutes, such as the CESAR institute in Recife and Eldorado in Campinas, also absorbed many of the skilled human resources.

The subsidiary sees that the formation of human capital was an important step towards building an ecosystem where the subsidiary could promote innovation. The partnerships established during this first phase of contacts evolved in other activities as well. Eldorado Institute, which received the original attribution for managing the Motorola-funded PCT project, integrated other projects that required shared infra-structure (such as the anechoic chamber, required for the testing of new products). Motorola was also involved in the creation of CESAR in Recife, aiming to create local job opportunities for the trained qualified people. The subsidiary also sponsored a group in Santa Catarina (South Brazil) to create new technologies for testing - CIn. These three partners became later key nodes of mandates acquired by the subsidiary in new products.

The initial different programmes had an important role in creating linkages between individuals in different organisations and formed the basis for some other forms of governance structured in the sector in 2003. The initial scheme based on voluntary funding from companies was substituted by compulsory contributions to a sectoral fund. Later on, changes in the legislation created a new sectoral fund based on compulsory contributions.

Even though there are further conflicts in relation to the politics in the governance of sectoral resources and the process of selection at sectoral level may not necessary represent the wishes of the companies that contribute to the sectoral fund, more recently, the redistribution of these funds has been organised in terms of public calls for projects to support initiatives in terms infrastructure improvement, training and research. (In fact, interviewees argued that there was a general bias against supporting companies already receiving the existing benefits).

Box 11 – CPqD and the disruption of the previous top-down policies for capability development

CPqD was created in the 1970s as part of the national policy to promote the accumulation of technological capabilities in the telecommunications sector. The unit had a fundamental role in the state monopoly of telecommunications given the import substitution requirements and the definition and development of Brazilian technology in telecommunications. During the 1980s, it became the most important research centre in the southern hemisphere (Hobday, 1986). By the mid 1990s, the privatisation of telecommunications in Brazil divided the state monopoly and regional companies were sold to both international and national groups to provide the telecommunications infra-structure in the different regions. During the process, the CPqD was transformed into a private foundation. In layman's terms, it meant that the institute would have an ambivalent mission. It would keep its characteristics as a political instrument to foment the national capabilities in the sector (therefore receiving 30-40% of its resources from a national sectoral fund - FUNTEL) and it would operate as a private organisation in the market (where the remainder of its resources should have originated).

The ambivalent nature of the institute was reflected in its social statute. The argued "privatisation" of the institute was not as complete as in a market economy. The institute has considered itself "an asset of the Brazilian people". Therefore, the composition of its administration board is based mainly on government indications and representatives of the internal body. The employees have considerable presence in its administration and the current president of the institute is one of the first researchers at the CPqD.

The investments inside the ICT Law were significant during the first few years in the institutue's specific projects sponsored by companies. Between 1993 and 2000, the institute was the second most important receptor of investments. However, in 2005 the activities inside the Law corresponded to as little as 3% of the total foundation revenues (the general budget was around 200 million reais), mainly related to technical services. At its peak, this proportion was higher than 10%.

The low number of projects related to the ICT Law could be attributed to two main reasons. As internal policy, the institute requires sharing the intellectual property of the product developed. This policy means that many of the key players in the market have avoided partnerships with the institute. In addition, given existing overheads in marketing and infrastructure of the foundation, the CPqD became more expensive than other research institutes and universities which specialised in providing development services,.

The main project inside the Law was related to a project sponsored by Solectron in 2000 (where CPqD retained the IPR), using an IBM platform. The project developed was a Business Intelligence Solution adapted by Telecom. This resulting product has been sold nationally and internationally by the CPqD. In subsequent years, the product was adapted to other industries (such as electricity, gas and water) and the group related to the product has grown to nearly 40 people.

The characteristics of the CPqD today are significantly different from the other research institutes in the sector, as it has specialised in consultancy services and in a general operation as a company trading its own products.

The foundation has participation in three companies (Padtec, Tropico and ClearTech) and a subsidiary in the US (CPqD USA). The institute has also helped the found the Institute Atlantico in the Northeast, where there is a stronger interaction with companies inside the ICT Law.

The institute also leads important initiatives coordinating national projects, and therefore, articulates more than 33 groups in universities and institutes. One recent example is the selection and definition of the Brazilian Digital TV system. CPqD also hosts a R&D forum (Fórum de P&D), that is composed of members of the scientific community and operates with the aim of prospecting new technological lines.

7.2.4. Technological consortia

Different forms of technological associations have proved important in sectoral systems around the world (Amsden & Chu 2003; Ernst 2000). In Brazil, different organisations, particularly private research institutes, emerged as key nodes of integration of new technologies and products. These organisations operate in a complex and dynamic environment, forging associations between government, universities, small and multinational companies. After strong investments in organisational development involving improvements in professional certification and quality standards, different associations and private research institutes have developed increasing autonomy for developing their internal projects.

For instance, FITEC had at some point an almost exclusive partnership with Lucent and managed to diversify to 12 different market segments (e.g. financial, commercial automation, electro electronics, energy, manufacturing, medical, sanitation, telecom suppliers and operators, IT and e-government). It has used its surplus to create its own research lines (e.g. UAV, VoIP, Auto-fit-metering and city-survey-palm tops). In 2005, the institute had their products in areas such as medical automation, power line transmission and non-manned airplanes. Although in some cases, the institute ventured into developing their own series of products, in most cases, the institute has shared investments and intellectual property with different partners. In 2005, just one third of their projects were related to the IT Law and, from that, 40% of the projects were inside the partnership with Lucent.

The migration from a project-based organisation (where services in product and process development are commercialised by hour), to a joint-venture model (where investments are shared and outcomes are co-owned) represented an important shift as the latter could provide sustainable sources of income, and therefore autonomy in future investments. There are still many institutes highly dependent on specific partners and in the incentives defined inside the regulation. Certainly in the short-run, the existing framework derived from tax obligations has provided them with a steady source of income. However, an abrupt change in the regulation is a horrifying prospect for different institutes. In addition, these investments are risky for organisations that operate on strict project-by-project budgets and many of their core partners, including mainly MNCs, are very reluctant in relation to shared property rights. Despite all the difficulties, different forms of consortia and joint-ventures between non-profit and commercial organisations are emerging and providing a way to diversify and promote a deeper integration of the technology into the sectoral structure.

The most important permanent linkages among multinational and national partners developed inside private research institutes. Some of these technology-based consortia (mainly private research institutes), once providers of human resources and equipment to particular firms, diversified their sources of income and became autonomous organisations looking for opportunities in the government, domestic and external market. There is a certain ambiguity of the possible aims of these organisations, allowing them to operate as private companies and articulators of the sectoral policy (as some of them may be certified as .Civil Society Organisations of Public Interest - Law nº 9.790/99), which includes receiving special treatment in government procurement.

Box 12 – CITS – Conflict between private and non-private stakeholders

CITS is a private research institute in Curitiba, South Brazil, created in 1992, as an articulation of 21 associate members from the private sector, local universities, and the local government. In 1994, it commenced develop projects inside the scope of the Brazilian ICT Law. Furukawa and Siemens became important partners inside the ICT Law, followed by HP and other large national companies such as Positivo and Bematech. It also established itself as a central node inside the software park of Curitiba and many other SME's became associated to the institute.

The institute operated in different configurations with a wide range of partners. Inside the ICT Law, the main partnership of the institute has been with Siemens, where the institute has a laboratory that supplies Siemens with approximately 170 employees. The group works relatively independently from the institute administration, although the institute has established monthly meetings with key managers to discuss general aspects of the partnership. Similarly, other partnerships inside the Law, such as Positivo and Bematech are mostly connected with providing human resources for the R&D projects. In the past, these partners had more than 50 employees each; however the groups have shrunk to a maximum of 10 people for each associated company. In contrast, the partnership with HP has been especially important in developing an internal software group. The first project was articulated between the subsidiary in Brazil and the demands from HP in the US. The internal group was based on the concept of a software factory, and this group expanded to provide commercial services. They were involved in large IT systems for the state government that encompassed more than 80 people at its peak and met the needs of companies in the aeronautics sector, such as Embraer and TAM, among others. The group focused in strong investments in process improvement and certification.

The institute suffered, however, a strong downturn in 2002, mainly attributed to the end of the largest project and mismanagement resulting from a 'hostile takeover'. Given the relatively large number of software SME companies among the associate members and the one-vote-per-associate system established in the statute, the general election of 2002 selected representatives from small companies to compose the board of administration. The new proposal was the reinforcement of the position of the institute as a political instrument to support the software companies in the region, and, as the institute was increasing significantly in size, it enforced a system that would suppress possible competition with the local companies for IT projects. The takeover, however, led to relative paralysis in the institute marketing actions, and the fluctuation in the number and size of the projects created strong financial difficulties and a trust crisis with established partners.

In 2002, after running at a large deficit for six months, the institute faced a strong downsising and the institute control was reversed back to the group composed of large companies, university and government. The strategy thereafter was retracted towards the original clients inside the ICT Law in order to gradually recover financially. This slow healing required two long years. In order to avoid further conflicts among stakeholders, there was a change of internal policies in which the institute would share the results of commercial projects with associated companies. The focus moved to creating sustainable complementary partnerships based on case-to-case contracts. However, the main strategic focus continued to be projects inside the ICT Law, despite increasing competition. Among other issues, the fierce competition meant that many companies expected to receive and then to select the ideas for the new products rather than simply order specified projects to be developed in the institute. This demand required developing another complete set of attributes for the organisation in order to design partner-specific proposals.

In this learning path, the regulations certainly allowed for the evolutionary appearance of technology-based consortia: the relative blurry property rights (there are no dividend payments in private research institutes, shares and/or payment of directors) which allowed for considerable experimentation in different statutes that defined the composition of the leadership and the rules of engagement with these institutes. In general, it also protected these new organisations from takeovers (at least in the traditional form, based on acquisition) and, whenever the governance allowed, internal groups developed a certain level of technological and managerial capabilities to explore new independent opportunities.

Box 13 - Brisa – an open private research institute

Brisa was created in 1988 as a forum for discussion, research and testing for interoperability and interconnection of communication networks inside the Brazilian telecommunications sector. Internally, the association was relatively small during the first ten years, with around 15 employees. But from 2000 to 2002, the institute grew significantly reaching 138 employees by the end of 2002. This growth was supported by a systemic increase in its activities in R&D provided to partners inside the ICT Law, although the institute had always involved activities of R&D with partners outside the incentives system, dealing with consulting and training.

The institute has a large variety of associates. In 2005, the institute reached a total of 127 associate members. In general terms, the associate members join the institute by a well established process, paying a small fee and therefore receiving general information about the activities of the institute as well as taking part in the election of the administration council. Internally, the institute is organised as a project based organisation. It has developed competence in embedded software for mobile, corporative applications, visual inspection of integrated boards and e-commerce, among others.

However, different from other private research institutes, Brisa is an association that has kept a great variety of clients. Inside the ICT Law, they have developed projects with multinational companies, such as LG, Alcatel, Lucent, Nortel, Jabil and Flextronics. During these partnerships, the institute accelerated the learning of software capabilities and duplicated its internal team. In project management, the institute developed a highly configurable interface with clients in order to provide complete transparency in the projects developed (.e.g the institute provides documentation both in its internal format and the client's format.). The internal process developed many good practices through the interaction with the multinational partners, including gaining improval through audits in international certification programs (e.g. CDMA). Moreover, the institute also made use of its weak ties to integrate capabilities of many other institutes and universities within research projects.

Brisa institute has been especially creative in pushing different coordination mechanisms that could sustain their capabilities. The lack of one strong sponsor requires a stronger market orientation in order to support the cost of the structure. Therefore, the diversification of clients was necessary for guaranteeing the organizational survival. The institute used a number of strategies.

First, some of the clients of the institute allowed Brisa to retain the intellectual property of the products developed. In these cases, they were aiming for the national and international commercialisation of these products. This internationalisation happened through representatives where the institute competed with established multinational companies. This strategy had however limited success because of the lack of complementary capabilities, such as local technical support.

Secondly, there was clearly a focus on keeping a lean organisation and maintaining a role as integrator. As most of turnover comes from projects, there was no margin for specialisation inside groups. The institute survival required a continuous flow of projects to maintain the internal team; therefore there has always been a constant pressure for new clients, new projects, and the articulation of competences in other institutes that would not require the increase in its internal assets and costs. In 2005, they had projects with UnB, USP/LAC, UFPR, PUC, UFRGS, Lactec, University of Bahia, CPqD, Genius and Eldorado.

Thirdly, the institute also developed a clear strategy for the establishment of R&D projects with partners that do not receive incentives. In this direction, the institute developed its presence in the media through marketing campaigns and targeted international clients in order to attract foreign investment in R&D. For example, they expected to bring 20 people for two years from an international company in technology that did not exist in Brazil. In 2005, just 50% of the R&D projects were related to the ICT Law, and the institute expected to enter into stronger processes of international learning during the next few years.

Box 14 -Eldorado – Corporate governance and the technological consortia

The institute developed a series of coordination mechanisms in order to operate as a system integrator in the sector, to work with increasing autonomy and to involve large companies in its administration board. As some of the companies on the board were competitors, the internal administration was not allowed to provide company specific information to the administration board, even omitting most of the information about the projects under execution. At the same time, the institute responded to strict self-imposed audits, provided by traditional financial consultancy multinationals, such as Ernst Young and KPMG. The institute constantly changed auditing firms as a mechanism to assure the transparency of their administration.

Internally, the institute was a private organisation. The internal administrators were mostly composed of personnel experienced in private companies[38]. The institute operated through the whole spectrum, from what could be considered almost hierarchical relations with clients to those which were almost market relations. In one case, they were involved in missions together with the subsidiary inside the multinational corporation in order to obtain additional mandates. With some of the partners, the institute had joint-strategic plan exercises in order to discuss all their R&D strategies and to define possible areas of development. Then they articulated the activities of partner companies in the south/southeast, with institutes and universities in the North/Northeast and Central-West. In contrast, partners constantly checked their prices against competitors in many cases.

There is no general intellectual property rights (IPR) policy and the agreements are usually discussed on a case by case basis. Nevertheless, the intellectual property rights of any development usually belong to the clients. This informal contract states that, as far as the client maintains its projects with the institute, the group that has the tacit knowledge related to the client projects will not be reallocated. However, if the investments cease, the institute will reuse the group in different ways. Therefore, the institute tends to maximise the reuse of the capabilities developed by another team. When it is not possible, the institute has transferred projects to universities or institutes that can sustain the assets, or, even transform the team in a spin-off.

A point of remaining conflict is the strengthening of a sales force. Given its nature as an association of companies, it is not allow to take part in marketing initiatives. Although there is a business development area, this area does not have any structure similar to a sales department. It is composed of three people that articulate and discuss possible developments in the partnerships. So far, the projects inside the ICT Law have stretched the institute to its limits of growth, therefore, secluding the institute from open market competition with software houses. In addition, given the growth of the institute, it also has developed policies to avoid becoming a predator of human resources from associate companies and to internal policies limiting the marketing of its competences in the media.

In fact, the main mechanism for the development of new partners has been the laboratory created for the testing of mobile technology. This laboratory was created with Motorola investments, but today, a wide variety and number of clients demand services from the laboratory. It has become a sustainable activity that attracts many companies. As regulated by Anatel, every product commercialised in Brazil requires testing by an Inmetro certified lab. The institute has become one of the five laboratories in mobile (NMI, CPqD, INPE and Labelo are the others). Inside this network, OCD institutions like TÜV, CPqD, Bureau and NCC forward companies to the institutes. This has become the main entry door for new partners in the Eldorado institute.

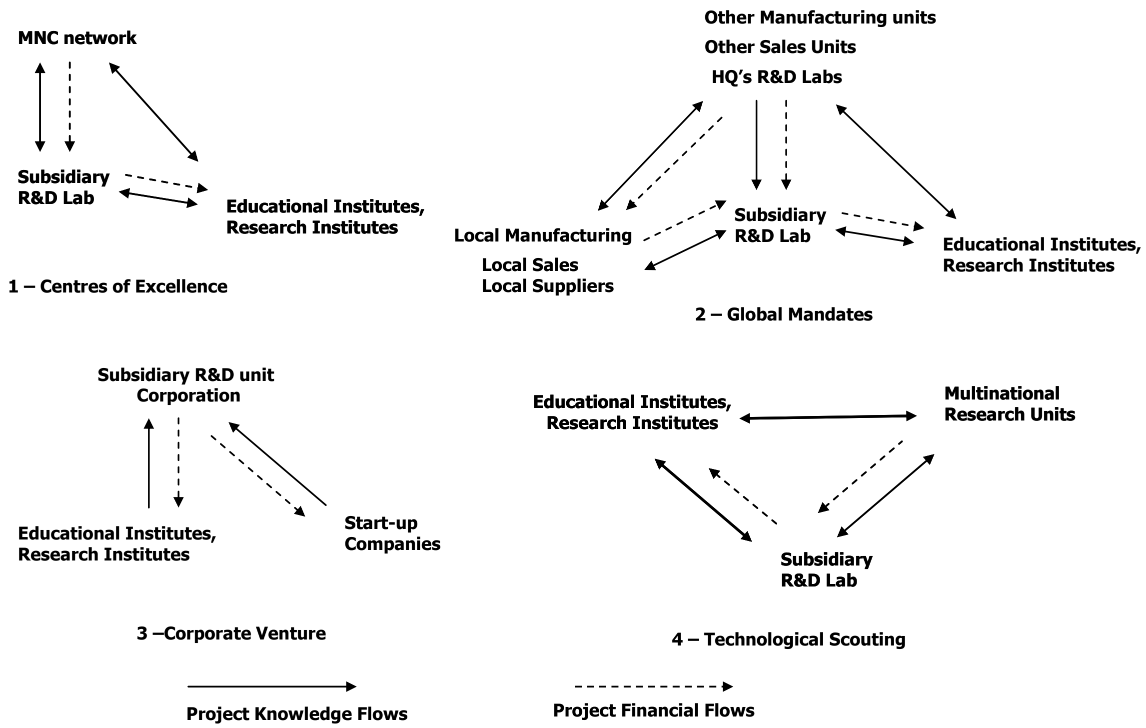
[38] with the exception of the superintendent who comes from the public national research institute for IT

A possible stream of future growth could come from projects for the government. In fact, the institute has an OSCIP certification, meaning that the organisation can avoid the complex and bureaucratic governmental procurement processes. However, , the institute has not yet been able to use this shortcut. Many governmental projects seem to avoid the use of the mechanism given the possible allegations of corruption or illicit selection.

7.3. INTEGRATED CONFIGURATIONS – GOVERNANCE IN COMPLEX SYSTEMS

Finally, there were a set of configurations that involved a stronger coordination among actors which shows how groups within configurations were identified: corporate venture, center of excellence, global mandates and technological scouting.

Figure 28 – Key configurations inside the developed networks.



7.3.1. Corporate Venture

Corporate Ventures are an important part of the way in which companies attempt to manage disruptive technologies in high-tech industries (Bygrave 2003; Ferrary 2003; Florida & Kenney 1988; Sahlman 1990; Tidd & Taurins 1999; von Burg & Kenney 2000). However, little is known about corporate ventures of multinational companies in developing countries like Brazil (Hobday & Perini 2006). The exploratory study showed that indeed some subsidiaries developed corporate venture funds financing disperse groups and promoted projects with academics and entrepreneurs.

Some subsidiaries refined complex procedures to receive proposals from academics and entrepreneurs and to examine them according to different internal needs. Some subsidiaries received up to 30 projects every month from established and new partners. A reasonable number of projects were business ideas from independent entrepreneurs. After receiving seed money, they created a number of new products in universities and even independent companies in areas where they found relevant interests. Direct results from the projects were intertwined with indirect benefits such as start-ups or developing games for mobile phones that could add value to the final users.

Slowly, some companies started to operate as systematic sponsors in the sector[39]. In the early periods these activities were sponsored without constraints to the researcher or local partner as it was not considered strategic for the subsidiary and multinational company. The sponsorship of a number of sectoral projects led by traditional research institutes in a consortium format was another result. With the systematisation, however, there was also an increasing understanding regarding the management of the contracts and a higher strategic intent on the returns. For example, Siemens had developed a Technology Portal and Awards to identify and analyse ideas from inventors and researchers.

However, the funding of new independent groups still tended to be a very small part when compared to the finance of projects led by private research institutes. An important stream of new ideas for projects started to be presented to subsidiaries by partners that already comprehended specific core technologies and even understood the "look and feel" of the subsidiary products.

Another common mechanism for the formation of new companies happened when groups working for the R&D labs eventually ran out of relevant projects from the original partner. Different groups started to pursue their own initiatives. Some of these new companies made use of other forms of support in organisations such as business incubators and venture capital (that were still very scarce in Brazil and were mostly provided by the government). Some of them became important new national companies.

[39] Important examples of venture-capital like activities were found in Solectron, Celestica, Motorola, Siemens and LG. Please refer to respective boxes for details.

Box 15 - Celestica - The establishment of a business model: between venture capital and OEM

Celestica is a contract manufacturing (CM) established in Brazil in September, 1999 as a spin-off of the NEC group. Celestica had also a second site in Hortolandia as an IBM spin-off, producing for large clients like Lucent and Dell. Following the increasing market near São Paulo, the units were consolidated in a new factory in Jaguariúna (on outskirts of Campinas), inside Motorola's technical park. Later, Motorola became one of its clients as well. In recent years, the subsidiary has usually introduced an average of 10 new products per year in their production line, sometimes from other sites, but mainly from "local" subsidiaries. Along the manufacturing activities, the CM has also acquired obligations related to the products.

During the spin-off process from NEC, Celestica became responsible not only for the manufacturing but also for the maintenance and technical engineering. Celestica had a group that worked together then with the NEC group on the introduction of new products. During this period, 6 products were jointly-developed and introduced on the production line. However, after the telecom bubble burst, NEC Brazil migrated to become a solution provider. Their manufacturing and product developments ceased and this internal group was closed.

Celestica did not have an internal team in 2005. The company used a large variety of institutes and universities, aligned with the diversity of their clients' technological needs . About 50% of their R&D projects came from clients that transferred their manufacturing activities to the subsidiary and the unit just supported the R&D activities of the technological partners following the client requirements.

However, the CM also acquired obligations related to the manufacturing when the client was not interested in R&D activities. In this case, the subsidiary focused mainly on the support of groups in universities and research institutes. The main focus was in groups that would develop products, instead of pure research. The expectation was that at some point these groups would require manufacturing of their products.

As a venture capitalist, the subsidiary received and analysed a number of proposals of ideas and partnerships coming from institutions all over Brazil. The subsidiary pre-selected the ideas based on the partners' reputation, and then, requested a presentation or more information. They usually approved about 10 proposals per year that were of interest. Some of them were a Radio Frequency/Optical laboratory group working in metamaterials and a microwave integrated circuit lab working in ballistic at Unicamp. In articulation with the Eldorado, the institute regionalised its investments, for example, investing in a partnership with UFC in wireless and with UniFor in internal software demands and artificial intelligence in board defect debugging (both in northeast Brazil).

Despite the previously mentioned shutdown of the internal labs in the past, the subsidiary started to reconsider an OEM-ODM path as a result of competitive pressures. Other competing CMs in Brazil created their own R&D units, providing, these R&D services to clients. Following this trend, the unit started to move towards a market-oriented development of innovative projects. Slowly the focus changed to identify clients and started to develop the products using the client brand. The first project in partnership was started recently, with Telemar - a large telecom operator in Brazil and was developed by a team of 6-engineers with Von Braun Institute.

7.3.2. Centers of Excellence

Although developing countries are usually assumed to be unusual places for Centres of Excellence inside the MNC (Chiesa 1995; Holm & Pedersen 2000), many subsidiaries have disputed this and obtained differentiated status inside the multinational network. Most of the capabilities developed came from successful integration and differentiation inside the multinational knowledge network and the development of a local “eco-system” of technological partners. Brazilian subsidiaries differentiated themselves into centers of excellence in specific technologies or components, avoiding direct competition with other emerging R&D units (especially in India and China).

The recognition as Centers of Excellence for specific technologies and products has important advantages. In most cases, the integration of the R&D activities resulted in the formation of matrix structures where local project managers responded directly to R&D units at headquarters and negotiated resources with specialised teams in different local divisions. Most of the interviewed R&D managers considered their direct superior to be in the HQ labs rather than in the local subsidiary. For the subsidiary, entering inside the global R&D structure was the key to maintaining their R&D teams despite the oscillations in the local market (and therefore regulated R&D expenditures).

By accessing, using and developing core technological capabilities company-wide, the subsidiary could profit from a stable income connected with corporate demands. Large R&D groups in the subsidiaries survived and thrived inside the corporation network.

Northern has had a Competence Centre in Mobile Technology since 1998 (150 engineers in R&D) (Box 3). Motorola Brazil (Box 16) had almost half of its 500 engineers in R&D in a group responsible for worldwide Messaging software for all the company’s handsets. Lucent Brazil shifted its investments more and more to software in new areas such as optics and mobile and Siemens Mercosur in Curitiba (200 employees in R&D) was among the top 5 R&D centres in mobile technologies. As a large part of the projects developed inside the main multinational companies were international corporate projects, interviews show that many subsidiaries used the required expenditure in R&D as bait for corporate projects: “a free lunch until the Brazilian unit could be seen as competent for the organisation”.

Box 16 - Motorola – Organising to compete in the multinational internal market for R&D (II)

Motorola emerged as one of the most important investors in R&D in the Brazilian ICT sector. The R&D activities in Brazil started at the end of 1996. Since then it has been among the leaders in investments in training, software, hardware, testing, and microelectronics. In 2003, the subsidiary, on its own, invested 30% of all the investments inside the ICT Law.

In 1996-97, the subsidiary group maintained a strategy towards the creation of the subsidiary's own mobile phone - a low cost mobile designed for the Brazilian market and its technological specificities. The subsidiary had therefore demand for embedded software, radio frequency and precision mechanics. Many of these capabilities were 'just not available or just too expensive'. After strong investments in the development of the different required set of competences, the mobile C535 became the first mobile developed in Brazil based on a three-year project. Alongside, the subsidiary attracted a series of mandates inside the corporation, including the global responsibility for the messaging software, and, more recently, the responsibility for worldwide testing of new handsets. In total, the R&D group that was created in 1996 grew in 2005 to more than 500 people involved in innovative activities. The first argument used for the creation of the R&D labs was that these investments were required by the regulation. However, the subsidiary has also been committed to making adequate use of the investments, creating competitive products and conducting the required complementary investments.

One of the aims of the subsidiary has been to develop a local team that could compete inside the corporation for R&D projects, not just based on cost and quality, but based on a good knowledge of the business, a more adequate timezone and a commitment to results. "We are competing based on our people who have a very high flexibility and good will. We are developing good relationships based on hard work." The international competition is very strong and the loss of some projects in internal competition generated insecurity. It is common to refer to India when the subject is software. The competition with Russia is also strong as there are very well qualified human resources coming 'directly from spatial agencies' to work in the MNC's". The subsidiary identified niches inside the organisation that appeared during the international reorganisation of its activities. Worldwide, Motorola responded to the global pressures through a considerable shift from a centralised to a decentralised organisation, where many regional bases and global bases coexisted inside the MNC. The instability of the global market imposed a consolidation after the internet bubble, opening threats and opportunities for the subsidiary. The Motorola group had to restructure around the world and 25 to 30 sites were closed, including sites in Australia and China.

Although in many cases it is inevitable, the subsidiary focused on avoiding direct competition with India and China for projects, mainly through differentiation and guaranteeing different mandates. In 2002, the subsidiary officially became the Messaging Centre of Competence (excluding MMS shared with India). Following the mandates inside the reorganisation, the unit became a strong regional centre and, in some cases, covered the products for the developing country group including India (although not East Asia). Currently, some of the attributions attracted, such as the global mandate for the test of new mobiles, have exceeded the required investments by the subsidiary and have involved shared investments from HQ.

The unit became responsible for the testing of every new handset inside the worldwide R&D chain: "If we stop our R&D, the global Motorola stops". The new attribution happened after the recognition of their competence in software (developed mainly through the outsourcing of activities), hardware and tests (developed inside the subsidiary mobile handset project). The possibility of the recombination and integration of these competences developed in three different groups made the new global mandate possible.

Although mandates created a certain level of security, the sustainability of the R&D activities requires the constant search for new attributions. The dispute with other subsidiaries also happened outside the R&D activities. Some products developed by the subsidiary for global telecom clients were very successful, and, therefore they were transformed into a global demand from the global client. The global client then had direct contact with the subsidiary in Brazil, creating tension in the internal attribution of markets.

This global integration is also associated with some disadvantages. First, unsurprisingly, this increased integration resulted in a decreased autonomy. At the end, as discussed in the middleware trajectory, global project managers were responsible to allocate the projects that would be conducted in each location, and the units become more and more dependent on these assignments to maintain the existing groups. Consequently, a reduction in the ability of the subsidiary to identify and react to technological discontinuities can occur and cause vulnerability to changes in the product technology.

Entering into the MNC funding structure sheltered large local R&D units against the volatilities of the internal market. The sustainability however depended on a project to project development of trust, quality and creativity and a constant identification of project opportunities inside the MNC.. The bargaining power of the headquarters is vast in some structures and the global downturns and upturns become very important to the local units.

It is important to observe that centers of Excellence were not perceived as stable positions. Indeed, the global project managers could induce inverse knowledge flows among different units. For instance, in the case of Dell’s subsidiary, the unit was the first off-shoring unit inside the multinational company. They developed new processes required for professional off-shoring, as it was not systematised inside the corporation. Recently, they were responsible for the transfer of many of these processes to other units in India and Russia (in principle, their “direct competitors”).

Box 17 - HP - Organising to compete in the multinational internal market for R&D (III)

The trajectory of R&D activities of Hewlett-Packard in Brazil started in 1986 with the acquisition of Edisa (a printer manufacturing company) in Gravataí,South Brazil. The incentives of the Law have been used since 1997, and the subsidiary has experienced a smooth growth in the investment requirements through the years. Today, the company spends more than twice the amount required by Law, and this proportion was higher before the merge with Compaq. The technical body acquired in the national company initiated the foundation of the R&D department in 1986. During the first period, the R&D projects were local and they were used to show technological capabilities to headquarters. Since 1997, the ICT Law has worked as a mechanism to support the subsidiary in attracting projects from diverse business units (PGU Labs). Focusing on sustainability, each project that was developed locally was integrated in the multinational developing network. HP Brazil had more than 80 employees allocated to R&D activities in Porto Alegre, South Brazil and an extended network of more than 20 different partners that represented up to 250 people involved in innovative activities. The subsidiary is particularly active in the internal market. In order to build new relations, in many instances, the subsidiary has provided initial services at a reduced price. Through the discounts, the subsidiary proved its capabilities convincing new areas to bring activities to Brazil. In their words, a "free lunch" created new partnerships.

The subsidiary has kept in mind that in order to compete in the internal market for R&D projects, costs are not everything. The quality and results of each performance have been fundamental. Each project has been evaluated according to short-term metrics, following global industrial standards and frontier technologies. In addition, new areas are referenced to other areas where projects are already developed. The result of each project was fundamental therefore to build a trust inside the multinational and accumulate new partners. The unit served a large number of internal partners becoming an 'internal global system integrator' and took part in the conceptualisation process of most products and technologies developed by HP. The subsidiary took an important integrator role in global R&D projects inside HP. Through the years, the subsidiary built its name providing services to different units. As the subsidiary involved itself with a larger number of internal units (e.g. Image and Printers labs, Corporate System labs, Personnel System labs, Services labs, and, even, HP Labs - main units of research), they learned and acquired competences from each one of them. The complementarily of the knowledge developed at the subsidiary was therefore, strategic for its development. As they had large departments in each business group, business units and product line, the subsidiary had capabilities to articulate knowledge in different units.

Throughout that time, the subsidiary did not fit into any of the large HP divisions and became an internal integrator directly connected to the HP Labs management (HP Labs are the research labs inside the organisation). The subsidiary developed a differentiated position, therefore, much less vulnerable to the costs under global demands. For instance, it avoided direct competition with India. While in India, there is a HP Lab responsible for emerging countries, the unit in Brazil is connected with the high-tech research: "It means that we presently take part in a large part of the product conception in HP and we now do not need to go after new projects at the division. The projects, more or less naturally, come to our subsidiary and local partners. […] There is no way to be humble about these achievements". However, despite a relative advantage in the cost-based competition, the subsidiary is in highly demand in terms of quality of research. They are connected to the global team and, therefore, they are assessed against other subsidiaries that have a rich environment in terms of partners. This position, therefore, reflects a high demand for the technological partnerships in Brazil.

A simple matrix structure is not adequate to describe the organisation of some of the most diverse multinational companies. In some cases, companies provided services to a large number of internal divisions. Motorola Brazil, for instance, became responsible for the testing of all new corporate handsets by integrating capabilities developed in hardware, middleware and software at different moments and in different projects. HP in Brazil, after supporting many internal divisions, differentiated itself so much from other units that it become directly connected with the corporate labs (the HP Labs) given its capability in system integration in a wide range of products (see Box 17). The subsidiary in Brazil differentiated itself from labs in India and China that are responsible for technologies for developing countries, as the labs in Brazil are in connection with leading edge corporate research. This requires building a network of partners that can sustain this differentiated position inside the corporation. However, considering the limitations in the local dynamism when compared to main global centers, it is possible that the life-span of these centers of excellence in developing countries tends to be shorter than their counterparts in developed countries.

7.3.3. Global Mandates

Some subsidiaries developed *global mandates* in specific products inside the industrial corporation (Birkinshaw, 1996). These mandates were usually the result of historical competences available to the acquired companies that used the established complementary capabilities in the multinational to expand the traditional products. For instance, in June 1999, Lucent entered the Brazilian market through the acquisition of two main national telecom companies, Zetax and Batik. The acquired companies specialised in small PABX (switchers with low number of access points - ZTX-610 and Elcom), a product not available inside Lucent at the time. The Brazilian lab transformed the previously local products into global ones, therefore, it was responsible for the BZ5000 that was sold worldwide through Lucent's distribution channels.

In 2005, there were no more sales of the product in Brazil yet the subsidiary remained responsible for 100% of the improvements on this product that was sold mainly in Asia. The subsidiary successfully combined the competences acquired in the national companies and the linkages within the international group, using the "best of the two worlds". However, the product suffered a discontinuity worldwide. The product became mature and the next generation of the small PABX inside Lucent was based in California with a company that Lucent had recently acquired. The loss of the worldwide responsibility for the small switchers was especially disappointing for the subsidiary. The next generation of this product could become one of the leading Lucent products worldwide.

Box 18 -Lucent –the rise and fall of global products

In June 1999, Lucent entered the Brazilian market through the acquisition of two main national telecom companies, Zetax and Batik. The subsidiary had received strong incentives between 2000 and 2002, with the large demand in telecommunications. However, the market (and consequently, incentives to R&D) dropped significantly during the following years. After the acquisition, the group of acquired companies corresponded to 70 people allocated in R&D. In the subsequent years, the group grew and attained a level of 300 employees by the end of 2002. However, the market change enforced significant downsizing and the laboratory in Brazil had only around 105 employees in R&D by 2005. The subsidiary still needed to invest more than three times the amount required in the legislation to keep up this level of R&D activities.

The local R&D group was divided into three main areas of competence. The first one resembled the the acquired companies' important products, which were specialised in small PABX (switchers with low number of access points - ZTX-610 and Elcom). The Brazilian lab transformed the previously local products into global ones and therefore, was responsible for the BZ5000 that was sold worldwide through Lucent's distribution channels. Although there were no sales of the product in Brazil anymore, the subsidiary remained responsible for 100% of the improvements on this product which was sold mainly in Asia. The subsidiary successfully combined the competences acquired in the national companies with the linkages within the international group, using the "best of the two worlds".

However, the product suffered a discontinuity worldwide. The product became mature and the next generation of the small PABX inside Lucent would be based in a company that was recently acquired by Lucent in California. The loss of the worldwide responsibility for the small switchers was especially disappointing for the subsidiary. The next generation of this product could become one of the leading products inside Lucent worldwide. In fact, the subsidiary had been working hard on a substitute product (i-Gen), but, given a combination of changes in technology, failure to deliver the internal project on-time and an impediment of internal resistance, the Next Generation small digital PABX project lost its political support inside the MNC network and the project was cancelled while the local product was already under test. This group decreased significantly in 2004, when a reduction was made from 80 to 35 engineers. The cancellation condemned the growth trajectory and the subsidiary's mandate.

Box 19 - FITEC –From Lucent's institute to a full-fledge system integrator

Fitec was the result of a merger between two institutes: FGA (Fundação General Alencastro de P&D Tecnológico) created in Belo Horizonte/MG in 1997, and the FPDIAT (Fundação de P&D em Informática Automação e Telecomunicações Aldemar Parola) created in Campinas/SP in 1994. These two institutes were preferential partners of two national companies, Batik and Zetax in the development of digital switchers. After the acquisition of these two national companies by Lucent, the administration of the two institutes also merged in 2001, and Lucent became the most important technological partner in Brazil.

The technical body developed in these partnerships still remained the basis of the institute However, the institute expanded from 70 engineers in 2001 to more than 300 engineers in 2005. The unit in Campinas includes 130 engineers, the unit in BH has an average of 85 engineers, and the recently created unit in Recife comprises 70 engineers. The institute's strategic challenge was diversifying and transforming itself into an independent and self-sustainable system integrator in the sector. Even with volatilities in the demand from Lucent, the institute managed to sustain a high growth rate during recent years. In 2005, the administration council was composed of three members: two were ex-members of the Ministry and the other was from the IEL. In general, the institute was quite independent in deciding its overall R&D efforts. Until 2002, Lucent had a position on the board, however, following internal negotiations, the institute and the company decided that the partnership would be more transparent without this direct involvement and the subsidiary stepped down from its position.

The growth of the institute was impressive. During the early stages of the merger, the main partner, Lucent, had considerable control over the executed projects. Related to the IT Law, the institute also expanded to partnerships with Jabil and Semp-Toshiba. The ICT Law allowed the creation of certification laboratories, (e.g. cable tests). Throughout the years, these laboratories became an important channel of interaction with local companies and the institute upgraded its installations through the diversification of partners. Given the volatility of the project-based structure, the institute could not maintain internally highly-specialised competences nor expect to develop commercial and production capabilities related to the newly developed products. Therefore, with interaction with other institutes and universities as a requirement, it developed projects in partnership with a large number of institutions, among them Genius, Unicamp, Inatel and PUC-MG. The institute has strategically focused on projects in co-execution with other institutes, and in governmental projects, such as the National Digital TV standard. For instance, in relation to this project, the institute is taking part in four of the 19 work packages coordinated by CPqD. In these projects, the institute also worked together with local companies such as IECOM, CESAR and UAB. In general, the institute expected to develop ways to license these technologies to these examples and other local companies.

The second phase involved strong investments in learning and the unit increasingly received autonomy for internal projects which were aligned with improvements in professional certification and quality standards. The institute remained mainly a project-based organisation, focusing on the development of middleware as well as maintaining a constant involvement in professional qualification. However, the institute used its surplus to create its own research lines (e.g. UAV, VoIP, Auto-fit-metering and city-survey-palm tops). In some cases, the institute shared the intellectual property with other partners and, in other cases; it was responsible for 100% of the investments required, thus keeping the respective intellectual property. In 2005, the institute had their own products in areas such as medical automation, powerline transmission and non-manned airplanes. It diversified to 12 different market segments (e.g. financial, commercial automation, electro electronics, energy, manufacturing, medical, sanitation, telecom suppliers and operators, IT and e-government). In 2005, just one third of their projects were related to the IT Law and 40% of the projects were inside the partnership with Lucent.

This example shows the complexity of the opportunities to sustain global products inside the MNC network. Developing global products allows subsidiaries to explore the global channel of distribution and sustain large teams and networks of global and local suppliers of technology. This usually requires a close connection with leading users also and this is usually the key limitation of this configuration for subsidiaries in developing countries.

There were some cases where local products developed by subsidiaries to attend to specific needs of the rural areas managed to be converted into global products. One of the most successful projects developed for the local market, and then sold abroad, was the DLU/Shelter, a self-sustained switcher for remote rural/ less-populated areas adapted to the disperse population in Brazilian territory. The product, initially developed for the Brazilian market, became a worldwide product sold by the Siemens' subsidiaries especially those in developing countries.

Another trend is the development of local products for global players. Some products developed by the Motorola subsidiary for global telecom clients were very successful, and, they were transformed into a global demand for the global client. The global client then directly contacted the subsidiary in Brazil, creating tension in the internal attribution of markets. At that moment, however, the relative position of the region in global trade means that this configuration has remained an exception.

7.3.4. Technological scouting

Finally, technological scouting (Tidd & Trewhella 1997) was pursued by a number of subsidiaries. This final configuration is especially surprising in a developing country. Some multinational companies have ventured resources for the development of the eco-system of relationships with universities and research institutes where they could promote the research groups aligned with multinational corporative needs. This alignment would influence the formation of human resources in universities as well as improve the general infra-structure and the provided technological services.

In addition to pursuing an alignment between local and global networks, the subsidiary intended to be able to explore new product development opportunities as they emerged in the multinational. Hence, in addition to the contribution to the MNC as a whole, the subsidiary aims to improve its own competitive edge in relation to other locations.

Indeed, some subsidiaries were actively proposing alignments between the research activities in partnership with the activities in the global network. This is an important configuration emerging recently when a few subsidiaries started to see research activities as a factor of strategic importance. As R&D groups increasingly competed with other subsidiaries for internal projects and groups were threatened by the end of the life cycle of different products, the involvement of the subsidiary in earlier phases of the corporate technology started to be seen as the key to identify technological opportunities and to prepare for future corporate demands. Rather than having to compete during the last phase of the product life-cycle when headquarters are pressured by costs to outsource R&D activities to lower cost countries, the subsidiary would be able to differentiate and be involved much earlier in the corporate roadmap. Then, local groups could grow organically in the organisation from there.

Companies like Ericsson (Box 20) and HP (Box 21) implemented organisational mechanisms aiming to align research activities developed by partners in Brazil with the network of research in their global research network. By sponsoring local initiative and conducting periodic explorations inside the multinational corporation, these subsidiaries expanded their strategic position inside the corporation integrating local and global networks of research. In many aspects, this international alignment of research activities differs from product development centres. Mainly, as pointed out in the previous chapters, it is formed by a wider spectrum of partners and relatively weak ties in the knowledge network.

Box 20 - Ericsson – Promoting global research networks

The subsidiary has an important role in the development of research activities in Brazil. The company has organised itself to receive and analyze projects from universities and coordinate the local portfolio of projects within the interests of the worldwide group.

They examine an average of 50 to 60 projects per year, selecting about 25% of them. The linkages between the local research and the corporate research portfolio are conducted mainly through travel to promote Brazilian competence and to convince the internal Ericsson Research that there are groups in Brazil able to contribute to the global research, mainly: "that we are not just a bunch of inexperienced scientists in the middle of the jungle".

These trip take place about 4 times a year. However, there is always a challenge that the amount allocated to these activities varies according to the internal market and the demand from the global market in development activities. Therefore, the oscillations are very challenging as they require an adequate number of good projects in the pipeline.

Box 21 - HP –Reaching the core of the MNC research network

The company has developed an extensive network of partners by using a strict code of conduct which focuses mainly on the sustainability of the relationships. Different from other subsidiaries, the company has avoided developing one or two preferential partners and has rejected the temptation to create their own research institutes or take part on boards of directors in different institutes and universities. At the same time, the company has enforced strong control over intellectual property.

The company does not consider participation in the boards a good practice. The close contact is thought to increase the orders from these institutes. The subsidiary keeps an "arms-length" distance from the partners where they can extract win-win relations without the expectation of the partner to create a dependency of companies on its boards, providing additional transparency.

The company also controls each partnership closely and is strongly oriented towards the company goals. In this sense, the company considers it against the 'spirit of the law to promote philanthropy' using these resources, as the maintenance of each partnership is expensive and it should increase even without the incentives. It means that the incentives are just a mechanism to enable the first steps of the partnership in activities where the company has a strategic interest.

The subsidiary also has strong policies regarding intellectual property. The participation in core products and HP research globally does not come without pressures from the local community in terms of the appropriation of the results. The company has aimed towards excellence of research, articulating projects and events with the local community and with global scientists: "Last March, we brought 25 people from HP Labs to a conference here for three days talking about High Performance Computing Grid, manageability and virtualisation". For example, the technology is so critical for HP that every participant had to sign a non-disclosure agreement.

On many other occasions, there are good people inside Brazilian institutes and universities that are invited to be integrated into the global network. However, the policies of the university or institute related to intellectual property are crucial whenever researchers are invited to take part in the international R&D projects. Thus marks the difference between a central role and a peripheral role.

The key for developing a sustainable investment in research could not come directly from the IPR developed by the subsidiaries. However, the administration of IPR tends to be centralised in HQ and in turn, central labs such as HP Labs and Bell Labs need to decide on the centres for future research. This imposes enormous challenges for the subsidiary development as they need to be considered an adequate source for long-term research financing. In addition to the fight against the stereotype of a subsidiary in a developing country, the subsidiary needs to justify the existence of an eco-system of research institutes and universities that are connected to the subsidiary, not just capabilities related to the internal team

Following this strategy, there is a limited re-emergence in the interest in the relative ‘traditional’ centres of excellence inside the sector. CPqD, the previous state technological institute for telecommunications, is the most important receptor of research investments, followed by private institutes and universities in the region of Campinas and Curitiba. Unicamp is one of the best equipped universities in Brazil and it has attracted an important part of the investments in research.

Meanwhile, the new private research institutes consider research strategic for their own diversification. For example, the Inovativo programme in Informat has promoted considerable investment in research by their own employees in order to identify new streams of business (see Box 22). Many institutes also have recently established a technical council, where the institute sponsors scholarships in partnership with prominent researchers to pursue some internal projects.

Box 22 –Informat – Sponsoring new research areas in alignment with global networks

The Informat institute works as a large project-based organisation, but it is also divided in 'cells' as a way to separate groups involved with different partners. These separations may require even different areas with separate network and access cards. The different groups have expertise in software languages, communication networks, signal processing, cryptography, real-time systems, RFId, and software for mobiles.

There is, therefore, a recent structural shift towards diversifying its competences. Although the institute has no intellectual property rights over the projects provided to Ericsson, the partnership provided enough resources for initiatives in other different areas. Since 2003, they have developed competencies in operational systems and WLA, Bluetooth. Since 2004, the institute has created competences in Automation, TM and innovative technologies such as Radio Frequency identification (RF-ID).

In order to diversify, the institute focused on internal mechanisms to promote internal generation and recognition of new business ideas. Integrating the institute's strategic planning (BSC) within the Human Resources department, the programme called Inovativo contains, for instance, possible negotiating shares in new business proposed by employees. The group has increased its investment in post-graduate formation at the masters and doctoral level without a necessary alignment of these scholarships with existing competences of the institute in doing so, it gives opportunities for employees to explore new areas of interest. In their words, "we are concerned not to steer the academic interests too much".

The institute also aims to develop its position in the market. The private institute intends to operate in the market as a software company investing in marketing and in participation in fairs. "Our main challenge is to disseminate that we are the largest private institute in the country. We believe we have made a great contribution to the sector". The institute is interacting with governmental projects for such items as a consortium with 25 open software companies in order to assure support to large companies that are migrating all their IT systems to open software. In addition, the institute also sees government-led projects as an important way to promote its image in the sector.

The institute is growing in autonomy and has taken part in associations such as ABINEE and ANPEI. However, it is relatively isolated without current projects with other research institutes. In many cases, they are seen as competitors. In some cases, a few conversations with other institutes were promoted by Ericsson itself, as the institutes were approaching the company for cooperation. The institute expects that the creation of a Technical-Scientific Council, a recently compulsory requirement of the ICT Law, would become a starting point for interaction with institutes in the region (e.g. CPqD, Wernher Von Braun and UNICAMP).

The institute is also expecting to explore the global market for R&D activities. For instance, instead of just receiving demands, the institute has started to propose some projects to the Ericsson group worldwide, such as solving conversion problems, and exploiting the expertise in Ericsson technologies (e.g. the knowledge in proprietary language, PLEX). The group is also reinforcing its commercial areas with expatriates experienced in units abroad in order to attract foreign investments in R&D from a variety of companies.

This naturally evokes questions related to how MNCs absorb the research developed in the Brazilian universities. Given the co-evolving nature of the capabilities and opportunities, it is sometimes difficult to determine whether these activities could be characterised as developing or draining local capabilities. Would the leadership of multinational companies configure an early brain drain of local skills and ideas and perpetuate dependency? Or would it be a small price to pay to get involved in these global research networks?

These topics are subject to considerable controversy. Indeed, different interest groups started to organise themselves into associations in an attempt to define a general rule in relation to intellectual property rights. However, there are fears that this will lead to additional rigidities and would easily hamper investments in more promising technologies. In principle, a more productive answer would involve expanding the number of organisations interested in the talents developed in the region and therefore creating more cross-fertilisation between interests of MNCs and other actors in the sector. Rather than regulation, a dynamic demand from companies and different forms of risk and investments shared among stakeholders seem to be the preferable solution among different stakeholders.

7.4. SUMMARY AND CONSIDERATIONS

This chapter uses a project-level analysis to categorise emerging configurations in the knowledge network formed between R&D laboratories in subsidiaries of multinational companies and technological and educational institutes. Twelve different configurations between innovative activities in multinational companies and the host country innovation system were identified and discussed. These recurring configurations identified are represented in Figure 26, 27 and 28, followed by their general characteristics.

The relationship between different groups of stakeholders and different configurations is summarised in Table 20.

Table 20– Main aims of the innovation projects in usual configurations

		Multinational network	Subsidiary (marketing, manufacturing)	R&D Laboratory	direct technological partners	other non-regulated companies/ organisations
MNC-centered configurations	**Local Products/ Processes**	Risk of excessive diversification and increasing coordination costs	Economic benefits from new/improved products and process (economic risk of failure)	**Capacity building, Technological and market links**	Capacity building / Income from R&D services (3)	Increased competition and better products in local markets.
	Certification & technological audits	New suppliers in the internal market	Improved systems	Capacity and reputation building	Capacity building (3)	
	Offshoring R&D	**Reduced cost of R&D activities**		**Participation in global R&D network/ sustainability of investments**	Capacity building / Income from outsourced R&D services (3)	
	Original Design Manufacturer	New services for global clients	New services for CM clients (4)	**Sustainability of investments**	Capacity building / Income from outsourced R&D services (3)	Collaboration with local brand leaders
SIS-centered configurations	**Technolgical Sponsorship**		Public image/ reputation	Identification of talent / reputation	**Capacity building**	Possible direct benefits
	Technological Supplier Development			Supplier development	**Capacity building**	Use of new supplier (2)
	Sectoral programmes			Outputs of sectoral projects (1)	Outputs of sectoral projects (1)	**Implementation of sectoral agenda**
	Technological Consortia	Possible new technologies and products (Worries about technology leakage)	Possible new technologies and products (Worries about technology leakage)	**Shared risks and investments**	**Shared Investment and reputation**	**Shared risks and investments**
Integrated configurations	**Global Mandates**	**Diversification, particularly in relation to appropriate products to DC**	**Economic benefits from global products and process**	**Core nodes in the global chain**	**Advanced technology and increasing relevance in the global value chain**	Increasing connection with external markets
	Centers of Excellence	**Incorporation of new core competences into the MNC**	**Increased understanding of global markets**	**Economic Sustainability of R&D activities and leadership status**	Economic Sustainability	Dynamism and technological leadership of local organisations
	Venture Capital	Possible new products	**Possible new product lines**	Complementary competences	**Shared Investment and reputation building**	New high-tech start-ups
	Technological Scouting	**Ideas /Talent scouting**	Talent identification	Differentiation of Capabilities/ earlier entrance in product life-cycle	**Participation in MNC R&D network/ Research outputs (2)**	Indirect benefits on educational/research system (2)

1. Depending on the priorities of programmes (may not incorporate interests)
2. Depending on property rights rules defined by company
3. When activities are outsourced to local partner
4. Mainly in contract manufacturing companies

The different shaded cells represent the core actors (dark grey) and participating actors (light grey) in different configurations. The table is useful to establish some general benefits obtained by different actors when engaged in specific configurations.

This chapter also has provided many examples of how different multinational companies and their technological partners have organised their activities around these emerging configurations. The results show that existing configurations in innovative activities are the fundamental organisational basis that defines the occurrence of possible knowledge spillovers as well as its direction. Specific interest groups may block newcomers and create lock-in in suboptimal organisational arrangements. Understanding these cognitive and structural aspects in the knowledge network is therefore fundamental if one wants to explore the implications of path-dependency as well as open up technological opportunities, improve efficiencey and/or expand benefits to a wider number of stakeholders.

The next chapter will connect these configurations with the dynamic analysis of the knowledge network in order to discuss some general implications for the alignment and misalignments in the sectoral innovation system.

8. OPPORTUNITIES AND CHALLENGES FOR THE KNOWLEDGE NETWORKS IN THE BRAZILIAN ICT SECTOR

> *"[…] the transaction as the unit of analysis is an insufficient vehicle by which to examine organisational capabilities, because these capabilities are a composite of individual and social knowledge. […] it is time to investigate what organisations do" (Kogut and Zander 1997)*

The previous chapters argued that the analysis of the project-based knowledge networks and emerging configurations are useful tools for addressing the alignments and misalignments between the evolution of multinational companies and sectoral innovation systems in developing countries. The analysis suggests that rather than general best practices, possible organisational interventions in the sectoral innovation system are contingent to the current stage of development of the underlying networks and available technological opportunities explored in emerging configurations. This analysis therefore contains an explicit practical component in terms of policy implications and institutional design.

This chapter identifies the specific characteristics of the innovation projects in the sector that promoted the sustainability and failure in the networks formed by different types of activities. It connects some details of the analysis presented in chapter 5, the comparative characteristics of the knowledge networks detailed in the chapter 6 and the emerging configurations discussed in chapter 7. This empirical analysis examines for each type of innovative activity, some organisational strategies and policy implications that could promote sustainability of the sectoral networks in the Brazilian ICT sector.

8.1.1. Enabling networks

The first group of knowledge networks to be discussed are those characterised by low levels of investments and where innovation projects were mainly outsourced to external technological partners. These networks are formed by four different activities: (i) the network of infra-structure and laboratorial equipments where there was an intermediate level of vertical integration and the analysis of the key-players showed the key role of MNC's and new private research institutes, (ii) the training in S&T network, where most of the projects were outsourced to technological partners although there is a considerable part of the training occurring in-house. (iii) the technological services network, where the analysis of the key actors and the correlation among the networks showed that the regulated technological services such as certification and metrology had an important role in establishing initial connections with research activities, and finally, (iv) research, where the analysis of the research projects showed that some centres of excellence developed considerable interaction between companies (mainly MNC's), universities and public research centres.

Table 21 summarises the main characteristics of the existing networks for each type of activity, the critical questions (or misalignments), and the opportunities as well as the limitations of the configurations present in each network.

The misalignment points were derived from the observation of the characteristics of the network structure and the elements that provided sustainability and/or caused failure in the different networks were derived from the common configurations observed in the sector. The specific opportunities and challenges are related to the development of each one of these networks in the Brazilian ICT sector during the period and they will be discussed as follows:

Laboratories and Infrastructure

From some interviews and literature in the sector, it is possible to observe a common generalisation that the large multinational companies tended to create relative 'captive' institutes. It was observed during many interviews in declared statements such as: "Institute [X] of Company [Y]", "the MNC's created captive private institutes", among others. Indeed, small or emerging partners were more flexible to attend to requirements from MNCs and had price advantages in relation to more traditional centres. These synergies were highlighted in different cases.

The analysis of the organisation of projects in laboratories and infra-structure resulted in four different organisational patterns. While some companies loosely sponsored infra-structure in universities and research institutes (a configuration called here *Sponsorship*), many other forms of governance emerged. In some cases, technological partners tended to have very limited autonomy and very strong integration with the subsidiary structure in an almost hierarchical structure. In these cases, most of the investments in partners were controlled by project managers in the subsidiary that used the projects to develop their strategy of integration in the global R&D network.

The analysis of the knowledge network showed a relationship between the investments in infrastructure and in training, therefore arguing for its role as a broader renewal of existing universities and public research centres. The general pattern of the infrastructure network is just weakly correlated with the software and middleware development network. This means that an important configuration was the large number of small projects that actually involved an interaction between companies and educational institutes sponsoring a widespread formation of small training facilities. The fact that these widely spread investments were not as visible as the new buildings may be a reason for these opposing patterns. However, this is certainly no excuse to ignore this more pervasive effect.

Table 21 - Organisational characteristics that promoted sustainability and failure in the enabling knowledge networks

Activity	Key structural characteristics of the network structure	Points under investigation in the specific networks	Sustainability (based on characteristics of the configurations)	Failures (based on characteristics of the configurations)
Infra-structure	• , Low/intermediate vertical integration • Low investments • Infra-structure was correlated with the training network rather them product development activities. • The analysis of the key-players showed the key role of MNC's and new private research institutes.	• Why did MNC's invest in new private research institutes rather than partnering with previous centres or universities?	• Large companies, particularly MNCs, sponsored decentralised infra-structure in educational institutes that could be reused by other companies • Resources sharing among companies created technological suppliers that could provide services to other companies in the sector. • Flexible forms of joint corporate governance allowed additional trust to be built among partners (mostly involving contractual mechanims) • Some of the sectoral programmes had an important effect, although in many cases they suffered from discontinuities	• Excessive dependency on original investors and interests of main sponsors • Institutes faced same level of discrimination when they are associated competitors • Limited investments and discontinuities in sectoral structuring programmes
Training in S&T	• The analysis of the firm-boundary showed that most of the training projects are outsourced but there is a considerable part of the training occurring in-house.	• How has these projects influenced the educational system in the development of human resources? And what is the role of intra-firm training in this context?	• Sponsorship resulted in changes in educational institutes to adapt and create courses according to company needs • Training human resources in new technologies aligned with global growth opportunities	• With rare exceptions, individual companies tended to focus on individual training needs rather than coordinated improvement of the educational system.
Tech. Services	• The analysis of the key actors and the correlation among the networks showed that the regulated technological services such as certification and metrology had an important role in previous research centres and a connection with research activities.	• How were technological services used in the formation of social networks among companies and institutes?	• Institutes engaging in formalised certification networks developed opportunities for interaction with a wide range of companies that need specific services	• As standards become increasingly open, Individual companies avoid initial investments in equipments (coordination failures)
Research	• The analysis of the research projects showed that some centres of excellence developed considerable interaction between companies (mainly MNC's) and universities and public research centres.	• What is the role of the emerging centres of excellence inside the system? • Who appropriates from the intellectual property developed?	• Some MNC's developed routines to align local and global research as a way to take part in early phases of intra-firm technology development. • Institutes with flexible policies in relation to corporate governance tend to emerge. The general rule seems to be that IPR is just shared in case of shared-investments. • New private research institutes have started to integrate researchers in the development of new products making use of other sectoral funds.	• As their internal product development teams and technology suppliers mature, company's-resources for sponsoring research tended to become scarcer. • Most of MNC's and public research and educational institutes tended to have irreconcilable policies in relation to IPR.

In some cases, subsidiaries had indeed a prominent role in supporting infrastructure in partners that would align global and national training with research activities. Resources were allowed to be shared with other companies and/or original multinational companies reduced their cycle of investments forming *Resource Sharing* pools in the sector.

In addition, companies supported programmes coordinated by the government in some common infra-structure investments inside *sectoral programmes*. This role was hindered by discontinuities in investment capacity from key agencies, and although some institutional learning has occurred and new forms of funding and coordinating sectoral policies were developed, most of these new mechanisms of sectoral governance just became fully operational in 2005 and suspicion still remained in relation to the legitimacy of their decision-making process.

Training in Science and Technology

Misalignment between the educational system and industrial demands for skilled labour should be considered a key challenge for innovation policies. Increasing attention has been given in the literature to the nature of university-industry interactions in recent years (Branscomb, Kodama & Florida 1999), pointing out that the intensity of these interactions, rather than simply academic excellence, is fundamental in historical catching up trajectories (Freeman & Soete 1997a; Von Tunzelmann 1995).

However, the university-industry interaction in terms of training does not happen naturally, as reported in many studies in Latin America (Velho 2004). The analysis of the projects sponsored by companies in training in S&T brings to the fore a key question regarding its role in the broad development of human resources. Specifically, how might these projects have influenced the educational system in the sector?

The case studies show that organisation of the training projects varied from hierarchical training programmes where R&D careers were developed inside the multinational internal programmes to market relations where companies sponsored individuals in existing courses in educational institutes in market-related transactions. Similar to the configurations in laboratories and infrastructure, some networked forms of governance emerged. The joint design of courses for a specific company-need is the first, more frequent, configuration (technological supplier development), where resources could then be shared with other interested agents.

This process happened to a great extent in a decentralised manner where small universities and educational institutions found new revenue in specific technological niches. Nationwide structuring programmes also took place sponsored by leading subsidiaries and followed by other companies and the government in more complex governance structures.

The strong correlation between the laboratories and the infrastructure network and training presented in the previous chapter (see section 6.3) indicates that in many cases the same agents were collaborating on related projects. Although an assessment of these interactions is far beyond the scope of this research, it is clear from the interviews that considerable effort and goodwill were required to bridge differences between business and academic cultures. A considerable amount of organisational learning was possible inside these projects allowing institutionalised inertia in business and academic practices to be overcome and routines could be developed on both sides that would allow the industrial and educational structure to work on common goals.

However, the difficulties in incorporating private demands in general curricula are evident. Some initiatives led by MNCs in improving curricula were not integrated into the government structure of incentives as a sectoral policy. In consequence, the resources allocated to this broader organisational change in universities have fallen systematically in recent years. The mechanisms used by different universities to incorporate the new demands of the sector are not clear in most of the cases.

In addition, companies were not particularly committed to promoting long-duration research training such as doctoral programmes. This results in particular limitations in the number of courses at the doctoral level in the sector. In this aspect, there is also scope for sectoral policies aimed at the coordinated expansion of research courses.

There were however a series of recent sectoral structuring public tenders focusing on the fixation of human resources in software engineering and general qualification of human resources inside innovative activities in companies, as well as the development of small groups[40]. The recent calls for projects have attempted to overcome some existing deficits, such as the low number of professionals with PhDs in software. Coordinated initiatives at the sectoral and individual company levels need to be expanded in order to consolidate the educational system and training and to respond to the demand for qualified human resources.

[40] RHAE-Inovação 2005, P&D para Capacitação de Pequenos Grupos Acadêmicos na Área de TI - PDPG-TI, Apoio à Capacitação de Recursos Humanos nas Empresas de TI - PAETI, Recursos Humanos para PITCE - RHAE Inovação, Pequenos Grupos Acadêmicos - PDPG-TI 2004, Recursos Humanos para PITCE - RHAE Inovação 2005, Interatividade e Fixação de Recursos Humanos qualificados na Região Amazônica 2005, Programa de Estímulo à Fixação de Recursos Humanos em Engenharia de Software.

Technological Services

The main sponsored suppliers of technological services were private and public research institutes. The supply of technological services created opportunities for many institutes that indeed benefited from the acquired equipment. Some of them discovered that there is an important development of weak ties around the provision of technological services, allowing for the diversification of clients (Eldorado and Brisa were important examples).

The coordination among companies and technological partners to provide technological services such as metrology and product certification established relations that strengthened other dimensions of the knowledge network. It is necessary to note however that the governance of these resources that is related to technological services, is deeply influenced by the proprietary nature of the technology involved. Although many research institutes have indeed received investments in equipment from sponsors, some of them could not diversify their clients given the interdependency between the testing equipment and the manufacturer-specific product. Therefore, these groups formed were also highly dependent on the original sponsor and operated in an almost hierarchical way (for instance, the sponsoring company feeling responsible for maintaining the group in the institute or university).

As ICT moves away from proprietary standards, opportunities for resource sharing expand. However, at the same time, this openness works as a disincentive for sponsorship of individual companies and the configuration of structuring programmes becomes more relevant. As well, the political nature of the joint funding mechanisms and decision-making process inside these configurations become crucial to determine the future competitive advantage of individual companies and the sector.

Research activities

The analysis of the research projects in the sector shows some important characteristics. First, as should be expected, most of the research sponsored by the companies in the sector does not aim to generate leading edge technologies but in fact aims to solve problems in an applied manner inside product development. A by-product is probably the main result. The research mainly involves the training of human resources at post-graduate level and the formation of small specialised groups in areas of interest for the company.

Secondly, multinational companies had strong restrictions in sharing the intellectual property of their investigations. It could be argued that the impossibility of patenting software in Brazil may lead the local market in a context less conductive for patenting in general and in a possible development of a patenting culture [41]. However, "culture" does not seem to be the main reason for the lack of patenting in the sector. The main reason seems to be that most of the multinational companies have strong economic reasons for avoiding cross-patenting with local institutes. These restrictions go beyond the usual expectations in terms of appropriation of the results of individual innovation. In a large part, it is the result of the systemic nature of the ICT innovations developed in the multinational companies, making it very difficult to disassociate technologies from products and the revenues. In this sense, the multinational companies avoid enormous transaction costs by having centralised funds resulting from any rent extracted directly or indirectly from IPR. The entry barriers to this kind of contractual partnership with the MNC's is very high. This is certainly an aspect that significantly limits the collaboration in the sector.

Nevertheless, emerging centres of excellence in ICT do exist, promoting the sharing of different types of intellectual property involving people and practices. Although in most cases, the importance and strength of intellectual property based on patents in areas where most of this research is conducted seems to be limited and the cost of patenting does not make it worthwhile. Companies will use other softer appropriation strategies such as secrecy through confidentiality agreements, organisational culture and trust-based partnerships. Meanwhile, significant technological advancement can be explored by the technological partner or a possible spin-off company as the MNC does not demonstrate direct interest in one specific development. This rationale may help explain some of the differences between the number of patents presented by companies in their reports and the number resulted from a direct search in the patent databases. Some patents created may have been registered and explored by other companies.

The results also show that the research network in the sectoral system exists, but it is still limited. Cooperation among the institutes is rare. The extent to which each institute cooperates with universities in research projects also varies significantly. Although there is an undeniable general willingness to cooperate and this act is an important element of technology diffusion inside the sectoral system, in general, the institutes are recognised for their professional capabilities, and more and more companies are inviting different institutes to tender in specific development projects, becoming direct competitors. Competition rather than cooperation is the norm.

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[41] By no means, with this remark, is intention to support a higher level of IPR protection in software in Brazil. The adequate level of protection should be understood in terms of the results in social benefits and this deeply depends on the level of technological development of the specific industry in the specific society. (Perini, forthcoming)

Few multinational companies were involved in research activities, sometimes sponsoring specific academic groups in areas of interest, sometimes more actively searching for possible synergies between the local networks and global multinational networks. The initiatives from Ericson and HP were particularly important. However, so far, the large MNC's are the only ones involved in systemic coordination as both venture capitalists. Direct government investments were very limited during the period but there are organisational mechanisms being developed.

One of the most important changes in the legislation from 2001 was the creation of sectoral funds which are mainly formed by compulsory contributions from the same manufacturing companies involved in the incentives. The first research projects started to be financed by the sectoral fund in 2003 becoming a natural development path for many private research institutes and an important mechanism for expanding the research-related network. As some research institutes are increasingly bidding for national tendering process sponsored by the sectoral fund, they have started to acquire increasing knowledge of their complementary competences. Given the usual structure of public funding for research, public institutes have had a relative advantage in research activities.

Public institutes with stricter internal IP policies become excluded from key technologies developed in subsidiaries. On one hand, the lack of bargaining power of scientists to negotiate better terms on the results of their inventions would be fundamental hindrance to the sustainability of these groups of excellence. Recent demands to add regulatory requirements for sharing property rights may increase the bargaining power of educational and technological institutes. However, most likely, it may further hinder the investments of multinational companies in cutting-edge research, and limit the possible opportunities for collaboration.

Public research institutes have also regained their role as coordinators of large research projects in the sector (e.g. the selection of the Brazilian Digital TV standard led by CPqD is one example). Greater cooperation is required for an alignment in specific technological trajectories from many disperse interests. The tendering process that is used in most of the official calls, benefit networked proposals and some institutes involved in cooperative activities. Expanding these initiatives is still a big challenge.

A long-term attempt to align national and international networks (or indeed the identification of core dynamic comparative advantages in the international trade) would required a complex mix of configurations that would support both large multinational companies in the evolution of their global knowledge network and the exploitation of the complementarities and spin-offs that would develop technological niches in the region.

These would need different mechanisms identifying promising new groups, relevant new technological niches inside the global research network development and resources for developing synergies among capable groups. In addition, the role of the government in sponsoring specific consortia and structuring national projects could certainly promote and facilitate the dissemination of a coherent strategy among the agents.

No pre-determined IPR regulation can support the many configurations previously mentioned. It is clear as well that it would be naïve to focus simply on academic excellence. The general IPR regime is still important as it may change the balance of power among different constituencies. However the dynamic appropriation of investments in research in a developing context remains a contentious, uncertain and risky matter. Diverse research funding structures and models of intellectual property sharing will need to be available in order to allow scope for the exploration of different opportunities.

8.1.2. Developing networks

This second group of knowledge networks to be discussed are those classified as "developing networks". These developing networks refer to the group of product development networks characterised by high internalisation and relative low level of investments. This involved (i) the quality systems network, where the correlation among the networks showed that quality systems had a strong correlation with the emerging software network, (ii) the semiconductors, which were the most sparse and internalised innovative activities, (iii) the process network, which was also sparse and internalised, and finally, (iv) the hardware-related network which is relatively larger but with strong turbulence.

Table 22 summarises the main points detailed in this section.

Table 22 - Organisational characteristics that promoted sustainability and failure in the developing knowledge networks

	Activity	Key structural characteristics of the network structure	Points under investigation in the specific networks	Sustainability	Failures
Developing Networks – Low accumulation, high vertical integration	Quality Systems	• The correlation among the networks showed that quality systems had a strong connection with the emerging software network.	• How is quality system connected to the formation of the capabilities in software?	• Key element in the competition for international off-shoring and local outsourcing	• Very high vertical integration of the projects hindering the diffusion of good practices
	Semi-conductors	• The dynamic analysis and the network structure show that the innovation projects in semiconductors were sparse and mainly internalised by companies. Although they have recently increased in importance.	• Which are the characteristics of the incipient firm-centric initiatives in semiconductors? How could they be cultivated?	• Some companies championed the trajectory in different moments. • New market opportunities such as Digital TV seems to involve allow the possibility of attracting manufacturing companies related to semiconductors	• Investments in other design houses in semiconductor described in the sectoral plan did not materialised. • The attraction of a manufacturing unit as well as the incentives to R&D for the TV boxes are highly uncertain.
	Production	• Similar to semiconductors, the dynamic analysis and the network structure show that these innovation projects were sparse and mainly internalised. Differently, these projects have a decreasing importance over time.	• Why so little (and ever less) production related innovation projects?	• Many Contract Manufacturers established their operations in Brazil integrated in global production networks	• The same CM's standardised production technology contains relative little scope for local R&D that would impact directly manufacturing productivity
	Hardware	• The dynamic analysis shows that there was strong turbulence along time in the role played by different actors. However, it resulted in a recent growth trajectory.	• Is there a shared model emerging? Which are its characteristics?	• Handsets and customised LCD TV require qualifications in precision hardware • CM's developed units for OEM development with explicit interest in subsidise hardware development as services added to their core business is production	• High vertical integration of the projects means that capabilities are not accessible to small companies (large companies could offshore to East Asia). • The consolidation around CM's may impose a risk to the large number of manufacturing SMEs in the sector

Quality systems

The investigation of the innovation projects related to quality systems showed that the projects in this category were mainly connected with the process of certification and qualification. This configuration was a key requirement for the transfer of world class practices to many units. In turn, this resulted in increasing productivity that allowed a limited number of selected institutes to establish themselves as preferential partners for key emerging players in the software trajectory. However, the network presented in chapter 5 shows that there were few ties related to quality systems.

The cases showed that both subsidiaries and institutes used the process of certification as a strategic advantage to develop their position in other networks. The quality improvements were transferred among the experiences accumulated in local product development, R&D offshoring and the ODM model into more complex arrangements in product development. Naturally, this is quite different from the configurations observed in technological services where projects were mainly outsourced in market-like relationships and companies were more eager to sponsor external infra-structure development and coordinated investments.

The fact that most of the investments were internal to the companies, may support the decision to exclude the support from this type of activities inside the legal framework. However, sustained investments in quality and certification remain fundamental for more advanced capabilities.

Semiconductors

This trajectory was immensely concentrated in the initiative of a few individual companies. Motorola was very important in attempting the re-emergence of microelectronics in Brazil[42] (Motorola Semiconductors is now known as Freescale following the international spin-off of the division). In 1998, the subsidiary created an IC design centre with 10 engineers, growing to 100 people in 2003. These were supposed to be followed by other centres inside the national programme in the development of Semiconductor Design Houses in Brazil. However, the other centres have not materialised.

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[42] According to preceding studies in the sector, Brazilian industry had substantial competences in previous institutions and national companies, such as SID, CPqD and ITI (MCT). These competences have decreased considerably after the liberalisation, and this area is one of the main burdens in terms of the Brazilian trade balance (more than 2 billion dollars annually).

A more recent undertaking in the development of the capabilities in semiconductors in Brazil has commenced based on the negotiations with the Brazilian standard of Digital TV. After negotiations that were conducted until 2006, the Japanese standard was selected predicated on the promise of investments in a manufacturing unit in Brazil. The new market for digital TV is estimated at R$10bi and it could create new incentives for investing in innovation if the same regulatory framework is applied to those companies exploring this market.

However, until 2008 the feasibility studies that would result in a manufacturing unit in Brazil have not been conclusive and the decision of the inclusion of the TV box as an ICT product inside the ICT law has not been reached. Despite some attempts to readdress the legislation, at the moment, the incentives are restricted to companies in the Manaus Free Trade Zone.

Unfortunately, it seems that limited knowledge has been crystallised in the industrial structure. While the early projects in the sector were mainly focused on developing local products, most of the disperse groups developing semiconductors did not manage to find their niche inside the international division of labour happening in the sector and they succumbed.

The absence of foundries in Latin America has also been pointed out as a key limitation in the evolution of the local network and most of the organisations involved in the projects in semiconductors were not able to develop significant economies of repetition as there was limited local demand for new products and, in fact, restricted investments in the national programme occurred. The possible contribution to a new cycle of opportunities related to digital TV remains full of open questions. Inside this scenario, even considerable investments may not enable the formation of an efficient knowledge network in this area, especially as digital TV technology is already consolidated in developed countries and most Asian emerging economies.

More recently, sectoral programmes have being redesigned around new incentives to attract and fix foreign investments in a plan coordinated around different agencies. The most recent news suggests that a semiconductor founder will be installed in Brazil in 2011. The outcomes are still far from clear. Inside the increasing globalised industry, these efforts might be too limited, too late as billions of dollars in investments are required to overcome existing entry barriers. Complex partnerships between public and private investors will be required to develop a sustainable trajectory in this area.

Production Process

According to the examination of the innovation projects discussed in section 5.3.7, there were still a reduced number of production-related innovation projects. Although some of the contract manufacturers invested in R&D for the creation and adaptation of their production line, it seems that the standardisation of the production process in electronics was so high that there was no need for higher investments in innovation in the production process. As mentioned in the interviews with contract manufacturers: “There is hardly any scope for the decentralisation of innovative activities in the organisation as, company-wide, the system is highly integrated in order to ensure the requirements of the globalised industry, such as transfer of a production line to any other site worldwide in 72 hours”.

However, disentangling the product manufacturer and the product owner has a further important implication for the funding of innovative activities in the sector and therefore their governance structure: the second tier suppliers (usually specialised in production), also outsourced the obligations related to innovative activities inside the ICT Law, thus, transfering the investment requirements in innovation to the contract manufacturer.

In principle, the regulatory framework required the company selling the final product to retain the obligations resulting from the outsourced production, and, in general, companies have kept the control over their R&D investments. However, some OEM suppliers have also outsourced the R&D activities from the main companies.

In some cases, these labs were among the first inside the global manufacturing network. Therefore, in general, the subsidiary activities in innovation tended to be completely stand-alone as there were no systematised R&D groups inside the multinational CM. For example, for Celestica worldwide, this was a deliberated strategy as they specialised in manufacturing services and avoided the development of own products. The creation of an R&D network overlapping the CM network would result in the conflicting interests of their clients.

However, other contract manufacturers, actors that were concentrating the production process in the sector, have used the resources to provide product development services for other possible clients, usually other companies with stronger brand and no focus on services such as banks, retailers and telecom operators. This resulted in a re-specialisation of the sector in hardware as detailed in the next section.

Hardware

The turbulence in the accumulation of capabilities was observed in both the analysis of the knowledge network and the in-depth case studies. This turbulence had important implications for the accumulation of capabilities. During the entire period, the local projects in hardware were widespread and fragmented. The accumulation that could happen through the multinational companies’ channel was not occurring as the subsidiaries found little space for competing in the international competition for R&D offshore units in this area.

During the first half of the period under analysis, most of the innovation projects were decentralised and mainly concentrated on national companies. Even among subsidiaries, many of the innovation projects in this network were related to local product development. A second wave of local product developments emerged from a different set of actors. Motorola developed capabilities mainly as a result of the need for the precise mechanics for a mobile handsets; LG focused on its internal need for adaptation of hardware in monitors. Some technological partners such as CEFET-PR, FCMF, CITS, CPqD and FEESC were involved in important projects becoming suppliers of R&D in hardware during different periods. However, the local demand is still limited. For instance, in CEFET-PR, the hardware capabilities developed in partnership with Siemens reduced significantly and it is now a spin-off inside the internal incubator. More and more, the first-tier of subsidiaries tended to use sister-companies in East Asia and China for the demands in hardware. The national companies have slowly increased their proportional participation as many local companies still need to use local capabilities for their needs.

However in 2005, it was possible to identify the strong role of the contract manufacturing companies as generic suppliers for multinational companies as well as national clients. The CMs had special interest in the development of capabilities in hardware, as it directly connects with their core competence in production. Solectron, for instance, is interested in a wider number of diversified ODM products that are sold under the brand of important national clients (e.g. low cost PC, ADSL modem, ATM terminals). The increasing number of centres created by companies such as Flextronics and Solectron (Box 6) show their potential to use this configuration for the accumulation of scale and scope in the R&D activities of a new system.

The reorganisation of the industry around ODM also opened up R&D offshoring opportunities, now inside the CM networks. As pointed out by Solectron's manager, there is an emerging trend in the worldwide CM network towards the creation of Design and Engineering departments, responsible for collaborative design. In this direction, the subsidiary is one of the first units inside the MNC with a R&D department and the responsibilities expand from local projects to the support of the Solectron group worldwide. It would mean the duplication of their local group in one year (from 40 to 80 employees) in order to meet the demands of the company's international market. In this sense, they have significantly increased their negotiation with other units, mainly in Taiwan, England and China.

Other CM's may need to follow the trend becoming providers of R&D services in order to keep up with the additional services provided by competitors (See Box 15 for the example of Celestica). Although most of the CMs are still limited to a strategy of development of infra-structure and personnel, this new CM-centred system seems to be a strong trend inside the hardware trajectory with possible implications for larger and smaller companies in the system.

8.1.3. Developed networks

The final group discussed here is related to the analysis of networks with higher proportional investments in innovation and where there a balance between innovation projects developed in-house and outsourced to technological partners. Table 23 summarises the analysis of the software and middleware related networks. These two networks are strongly connected as shown by the correlation in section 6.3, involving a complex governance structure and a large number of integrated configurations discussed in section 7.3.

Table 23 - Organisational characteristics that promoted sustainability and failure in the developed knowledge networks

Characteristics	Activity	Key structural characteristics of the network	Points under investigation in the specific networks	Sustainability (based on common configurations)	Failures (based on common configurations)
Developed Network – High accumulation, intermediate vertical integration	Middleware	• The dynamic analysis shows that there is a strong decrease in the number of projects conducted in this trajectory. It also showed that there is a strong link between institutes that emerged in this network and software network.	• What are the reasons for and consequences of the breakdown of the middleware-related knowledge network? How companies migrated to different opportunities in the software network?	• Many subsidiaries and research institutes enjoyed considerable investments related to the large national and international demand during the internet bubble (many companies have actually created Greenfield institutes) • Some equipments manufacturers managed to perform the transition from fixed telecom to mobile successfully (not just in the market place but also –and mainly - as R&D units)	• Traditional research institutes suffered from a crowd out effect where multinational companies articulated with new centres rather than existing ones • The burst of the internet bubble and consolidation of national market reduced required investments in major equipment suppliers and R&D groups became trapped in the competition with other units.
	Software	• The dynamic analysis of the software network showed a significant growth with increasing decentralisation of the accumulation of technological capabilities. • The analysis of the key-players showed the potential importance of emerging private research institutes in the diffusion of knowledge inside the network.	• Which are the organisational characteristics behind the fast accumulation of technological capabilities in software inside the subsidiaries? • To what extent institutes in fact operate as network integrators integrating and diffusing knowledge from different companies?	• Creation of many offshore R&D units to support new corporate demands. • Some subsidiaries developed and strengthened matrix structures with different units inside the corporation, coordinating different capabilities and acquiring unique competences and mandates • Newcomers in the sector identified synergies with existing institutes (rather than Greenfield investments). • The research institutes reinvested the profits in professional qualification and kept low overhead. (typically operating as system integrators). • Governance mechanisms developed in order to avoid lock-ins and allow operational flexibility	• The regulation constrains the private investments as it forbids the private research institutes to distribute any kind of profit on its activities and/or ownership on its created assets. • In some cases different interest groups in the board and the direct competition with local companies for projects in the marketplace generated significant corporate governance conflicts • The private investments in the private research institutes are hindered by their legal nature (not-for-profit organisations). Is there a scope for "corporatisation" of these institutes?

There are also important differences between these two networks. The analysis of the knowledge network showed that the middleware-related network investments were declining and vertical integration was increasing while the software-related network, had rising investments and increasing horizontal collaboration.

Naturally, for the complexity, in the networks that were formed by projects in middleware and software, many organisations were involved which were not the focus of in-depth case studies. It is important to note therefore that a comprehensive analysis of the technological developments occurring in these trajectories would be beyond the scope of the following analysis as these are the most diversified in both nature and number of actors. By focusing on the main agents of accumulation (a group of MNC's) and the agents of diffusion of knowledge (research institutes), this section aims to identify characteristics of the core configurations developed between MNC's and their technological partners in these relatively developed structures.

The results and contrasting dynamics are presented in the following discussion.

Middleware

The previous analysis of the sector showed that there were strong linkages between institutes formed in middleware through the connection with large companies and key nodes in the emerging software trajectory. The strong preferential suppliers were evident in the 31 ties greater than 1 million reais. The analysis of the network structure also shows that there was relative isolation between different subnets.

The most important reason for the decline occuring in this trajectory was attributed to the shrinking investments in fixed telecom after the year 2000. During the first four years of the period under analysis (1997-2000), the Brazilian telecom market was blossoming, given the high level of investments brought into place after the privatisation of the telecom operators. The privatisation process resulted in high investments in infrastructure which were required to improve the Brazilian telecom infrastructure network after the end of the import-substitution policy to specific levels that had been required by the privatisation process.

Rather than connecting with traditional centres such as the CPqD, the analysis shows that the multinational equipment manufacturers developed private institutes as key resource polls. The multinational equipment manufacturers dominated this large internal market post liberalisation, and as a consequence of the bourgeoning demand, the subsidiaries also had high levels of obligations inside the ICT Law. In addition to attending to the demand for customised products and processes, R&D offshoring units in companies such as Ericsson, Siemens, Alcatel and Lucent experienced strong growth. R&D offshoring was important for interconnecting with international opportunities within the MNC's demand during the internet bubble. The growth of these groups spilled over to preferential private institutes as they started to identify their niches inside the corporation.

In 2001, with the burst of the internet bubble, these corporations faced worldwide consolidation, resulting in strong pressures for downsizing. The decentralised structure that used to swiftly attend to specificities of the local clients was substituted by strong matrix structures with greater emphasis given to global managers that would coordinate global resources. There was a significant increase in coordination inside the global network and competition among the decentralised labs. R&D groups in Brazilian subsidiaries struggled to move into other technological opportunities in the corporation as many other decentralised labs inside the corporation tried to do the same.

At this point, the subsidiary's autonomy to pursue their projects was restricted. The reduction of the national market was also sharp in many segments, resulting in a proportional reduction in the obligations inside the ICT Law, and in an acid test for many groups. As observed in some cases, the path dependence and lack of autonomy led to an undesirable position where tax incentives became a mechanism for offsetting prices in the internal multinational market, allowing local groups to outcompete other subsidiaries as providers of R&D off-shoring services to the corporation.

From the network analysis and cases studies, it was possible to identify that not all the groups created were sustained over time. Some companies reduced their R&D activities at the same rate that the R&D obligations decreased. After creating important global laboratories during the 1990s, IBM, Alcatel and NEC had no R&D departments in August 2005.

The declining investments had an important side-effect as technological partners needed to identify new opportunities. In this period, newly created institutes recovered autonomy as the sponsorship of main subsidiaries declined sharply. Some of them had to go through strong downsizing (Informat for instance layed off 300 R&D engineers), while others managed to perform important organisational changes and diversify their capabilities and in doing so, generated their own products inside a reasonable smooth transition. With different degrees of success, the new private research institutes changed their organisations, opened up to a larger number of stakeholders, and adapted to become system integrators for the new opportunities opening in software.

Software

The strength of the software network was especially surprising as the initial policy was designed for manufacturing companies of electronic equipment. The Brazilian software companies that did not have manufacturing units attached were not eligible for benefits. Therefore, the universe of software companies in the sector was much bigger than those nodes represented in the network diagram. However, as discussed in other studies, the companies that used the investments inside the ICT Law were determinants of the current structure of the sectoral innovation system in software.

Large software groups created in the subsidiaries survived and thrived inside the corporation. Starting as R&D off-shoring units, many subsidiaries have disputed and obtained differentiated status such as “centres of excellence” in specific technologies inside the corporation. In most cases, the integration of the R&D activities resulted in the formation of matrix structures where local project managers responded directly to R&D units at headquarters and negotiated resources with specialised teams of different local divisions. Most of the R&D managers interviewed consider their direct superior to be in the HQ labs rather than in the local subsidiary.

For the subsidiary, entering into the global R&D structure was the key to maintaining their R&D teams despite the oscillations in the local market (and therefore regulated R&D expenditures). By accessing, using and developing core technological capabilities company-wide, the subsidiary could profit from a stable demand from the corporation.

The observed general pattern inside the sample reinforces the idea that MNC were key elements in the accumulation of technological capabilities. However, as could be expected, these companies operated in ways that systematised internal knowledge flow and avoided knowledge leakages in activities with local partners. However, rather than being entirely isolated, multinational companies have developed a considerable number of partners and technological suppliers.

Despite the very strong path-dependence in the original arrangement, in general, private research institutes have tried to introduce improvements in their corporate governance in order to avoid lock-ins and to allow for operational flexibility over time. There are probably a dozen software institutes in the sector that became mature suppliers and a considerable distinction between managers and “owners” emerged.

The mixed governance structure of these private institutes could be seen in two different ways. On one hand, these associations were an interesting variety of policy networks that could use the diffuse knowledge and sustain polls of distributed capabilities in the sector. On the other hand, the lack of property rights may be a recipe for disaster, where “players play poker with others’ cards”. The balance of power on these boards is high dependent on initial conditions, and there might be considerable scope for political manoeuvre that could be against the long term interest of the sector. The private research institutes differ immensely in the details they give on historical events and strategic direction from the different stakeholders of the board. Institutes developed a very diverse number of policies in order to protect the requirements of the different partners that at the same time would allow a certain level of autonomy, flexibility and transparency.

When the complexity of the network increases, general subsidies may become inefficient. The developed networks also enclosed a large number of project-based organisations that operated by integrating knowledge in these networks. Indeed, it was not just when the linkage existed that a possible knowledge spillover to the system would happen. When a linkage between strong partners failed, both subsidiaries and technological partners had to reorganise themselves inside the new context.

In principle, however, it should not be considered that a failure in a linkage is beneficial to the system. In general, the spillover derived from the dismantling of a highly differentiated group could be significantly dysfunctional. It takes a considerable time to form a group and make it operate efficiently in a specific technological niche. Although there might be an ideal level that is adequate, successful networks had a considerably stable accumulation of technological capabilities, rather than very strong “creative destruction”.

A plan to promote investments would be necessary for individual institutes and for the sectoral dynamic in the long-run. However, the existing fuzzy ownership structure may breed contempt among current managers and stakeholders with residual power. Specific groups may influence governance, and create inefficiencies. In addition, the regulation incentives would increasingly substitute (or even exclude) private investments in these organisations. The success of the software trajectory may be impressive, but further modifications seem to be required if one expects to allow sustainable growth and the reappearance of opportunities for emerging new actors and trajectories through the resources provided inside the framework.

There is no simple recipe for promoting the sustainability of this complex network. One might consider a stronger investment in technology diffusion, product development consortia, additional requirements and assistance to technology transfer. All these interventions would however involve risks, and no single model is a perfect solution.

8.2. SUMMARY AND CONSIDERATIONS

This chapter brings together the analysis of the project-based knowledge networks and the emerging configurations in innovation projects to discuss the factors that promoted sustainability and failure in different types of innovative activities promoted by the Brazilian ICT Law. Tables 20, 21 and 22 summarise the key discussions.

The analysis shows that the regulation may support higher investments in R&D, but it does not necessarily enforce a project portfolio that promotes local and global knowledge flow. The differences in the dynamics emerging in different innovative types of activities are clear proof of these differences. The diversity in the dynamics in different activities reinforces the fact that successful knowledge networks need to explore existing technological opportunities and to develop a multitude of coordination mechanisms among companies, government and universities and research institutes.

This chapter details how the organisation of innovation projects promotes the sustainability and the failure of the knowledge networks between multinational companies and sectoral innovation systems. Although companies tend to integrate the activities vertically that provide them with comparative technological advantages, they will also need to integrate external sources of knowledge interacting with different system integrators whenever rapid change occurs. In the development of new products during the period, the technological areas identified by the companies changed considerably, mainly from middleware to software. Clearly, companies inside the framework identified limited opportunities in microelectronics, hardware and production process showing that the same institutional framework can result in very different investment behaviours.

The analysis of the knowledge network and emerging configurations demonstrated itself to be a useful tool for examining these dynamics occurring in the Brazilian ICT sector. While technological opportunities clearly differed for different types of activities and substantially influenced the structures of the network, the analysis showed the diversity and multi-level nature of the governance mechanisms needed in order to integrate the disperse capabilities in these complex and diverse networks. Further policy implications and recommendations will be discussed in the next chapter.

9. CONCLUSIONS

This final chapter comprises a summary of the key conclusions, the main contributions to different streams of literature and implications for policy and management. It is followed by the boundaries and possible generalisations of the current research and outstanding questions for further research.

9.1. SUMMARY OF THE KEY FINDINGS

This research provides insights into how the institutional framework such as the Brazilian ICT Law can provide opportunities for the decentralised interaction between different organisations with very different interests and provide the tools to examine the organizational configurations which emerge over time. These results are related to a series of implications on the literature and policy.

The research questions and theoretical framework developed in the initial chapters argue that investigating the project-knowledge networks and the underlying organisational configurations can provide crucial elements for the analysis of the interaction between multinational companies and sectoral innovation systems.

The empirical analysis uses a large database of innovation projects in the Brazilian ICT sector and an in-depth investigation of case studies within multinational companies and their key technological partners. Using the knowledge networks and emerging configurations in innovation projects as key elements for the analysis, a number of different methods are used to provide insights into the nature of the interaction between multinational companies and the innovation systems in developing countries. Specifically, the knowledge networks in ten different types of innovation activities inside the Brazilian ICT sector have been examined: training in S&T, technological services, laboratories & equipment, research, process development, quality and certification and product development in hardware, middleware, software and semiconductors.

In chapter 5 and 6, a number of characteristics connecting the knowledge-base of the innovation projects and the characteristics of the knowledge networks formed between multinational companies and national innovation systems have been examined. Given the general characteristics of the project knowledge network, these ten types of knowledge networks were grouped into enabling, developing and developed networks given their differences in terms of in-house versus outsourced innovative activities and the overall level of investments inside the networks. This analysis also provides important insights into the three first research questions (summarised in table 24).

Chapter 7 develops an empirically-based and sector-specific taxonomy of these configurations emerging in the sector. Using the analysis of multiple cases, it was possible to construct a taxonomy of twelve different emerging configurations. These configurations are equally distributed into those centred in the MNC (i.e. local products/process, technological certification and technological audits, offshoring R&D and original design manufacturer), those centred in the sectoral innovation sytems (i.e. technological sponsorship, technological supplier development, sectoral programmes and technological consortia) and those that balance the MNC and the sectoral innovation system – called here integrated configurations (i.e. corporate venture, centres of excellence, global mandates and technological scouting). This analysis addresses questions related to the common patterns of interaction and the benefits obtained by different stakeholders in different configurations.

The elements developed in these two chapters provide a framework to discuss institutional interventions and organisational strategies to promote the sustainability of the fragile, complex and dynamic knowledge networks. In chapter 8, these characteristics of the knowledge networks and emerging configurations are applied to examine the dynamics in the Brazilian ICT sector and discuss specific elements that promote the sustainability and the failure in interaction between multinational companies and sectoral innovation systems. By triangulating the characteristics of the knowledge networks observed in chapter 6 and the emerging configurations observed in Chapter 7, it was possible to observe that the enabling networks are mainly composed of SIS-centred configurations, the developing networks are mainly formed by MNC-centred configurations and the developed networks accumulate the previous configurations and more advanced forms of integrated configurations. Therefore, it was possible to address the general reserach question related to how the underlying organisation of innovation projects in subsidiaries promotes the sustainability of the knowledge networks formed between multinational companies and sectoral systems.

Table 24 summarises the specific research questions, the dimensions discussed in the theoretical framework of interaction between multinational companies and the national innovation systems: the sections where these issues are described and the stylised results are portrayed.

Table 24 - Dimensions of interaction between multinational companies and host innovation systems

Research Questions	Dimension	Enabling	Developing	Developed
	Types of activities	Training in S&T Research Technological services (Laboratories & Equipments)*	- Process technology, quality systems, and product development in hardware and semiconductors	Product Development in systems and software
How do subsidiaries balance in-house R&D and external knowledge acquisition in different types of innovation projects?	Firm boundaries in innovative activities (section 6.1)	• Mainly outsourced to local partners (1) • Low level of investments	• Internalised • Low level of investments	• Mixed between integration and specialisation • High level of investments
Which are the patterns of specialisation in the sectoral knowledge networks?	Functional Differentiation (section 6.2)	• Technological Partners, mainly public research institutes and educational organisations	• Volatile investments in MNCs and domestic firms	• Sustainable investments in MNCs and domestic firms and private research institutes
How fast do inter-organisational linkages emerge and change over time?	Collaborative activities (section 6.3)	Two main communities • (Training and infra-structure) • (Research and services)	• Lack of articulation between communities of practice • Strong connection between quality systems and certification and developed networks	• Mainly MNCs and private research institutes integrating and recombining knowledge in different areas (in the case, software and middleware)
Which are the common organisational configurations emerging in the network between multinational companies and innovation systems?	Usual configurations (chapter 7)	Mainly SIS-centred configurations • Technological Sponsorship • Technological suppliers development • Sectoral programmes • Technological Consortia	Mainly MNC-centred configurations • Local Products/Processes • Certification and technological audits • Offshoring R&D • Original Design Manufacturing	Other configurations + integrated configurations • Global Mandates • Centres of Competence • Corporate venture • Technological scouting
• How would different stakeholders benefit from knowledge and financial flows in different configurations?	Governance (chapter 7)	• Wide variety of stakeholders • Relatively weak ties	• Limited diversity of stakeholders • Relatively strong ties	• Wide variety of stakeholders • Relatively strong ties

The first research question examines how subsidiaries balance in-house R&D activities and external knowledge acquisition in different types of innovation projects. Following a resource-based view of the project knowledge networks, the empirical findings support the literature that both the type of activities and the need to coordinate disperse resources influence the boundaries between firms and technological partners in the sectoral knowledge network. Innovation projects are used as a way to break into organisational boundaries and to explore the spectrum between market and hierarchies (i.e. networks) in different sectoral activities.

The results show that in-house R&D activities are related to product and process development activities in innovation projects, while outsourced R&D activities are related to other non-product development activities. There are clear differences between innovation activities that would promote decentralised networks or vertical hierarchies inside the sector. While in-house R&D activities are related to product and process development activities in innovation projects that include hardware, software, semiconductors, middleware and quality systems, outsourced R&D activities are related to other non-product development activities such as training in S&T, technological services and research. This general definition of the boundary of firms in innovative activities has been observed both for the group of national companies and multinational companies.

The results also show that increasing investments and rapid change increase the need for coordinating knowledge in the network. The two networks with higher level investments (middleware and software) exhibit a balance between outsourced and in-house R&D. Multinational companies are crucial to promoting investment and to shift investments towards software both in-house and with technological partners. The complementarities between in-house R&D and external capabilities are evident. Simply associating these different activities to public and private knowledge may not be a helpful distinction. and this would be particularly harmful if this was followed by an attempt to jump to simplistic recommendations about the type of activities that should be supported by public investments (e.g. an unique focus on research, training and infrastructure).

The second question explores the patterns of specialisation in the sectoral knowledge networks. The results show that different types of knowledge bases are required by different organisational mechanisms resulting in long-term specialisation in the knowledge network. Inside the project-based networks, foreign and domestic companies, educational and technological institutes, public and private organisations specialize and co-evolve performing specific functions inside the sectoral system.

As pointed out in the literature review, the division of innovative labour is central for the analysis of innovation systems. However, the existing empirical literature clearly disagrees regarding the role of different organisations. The analysis of a project-based knowledge network provides an assessment of each of the functions which are performed by different organisations and therefore provides insights on how the sectoral innovation system really worked during the study period.

The analysis of the patterns of specialisation shed new light on the distributed innovation process occurring in the Brazilian ICT sector. Recent academic discussions in the sector have been heated as authors investigate different patterns, for instance,the process of liberalisation has resulted in decreasing capabilities in the cluster that were previously concentrated in domestic firms in Campinas (Szapiro & Cassiolato 2003), the active role of policy and multinational equipment manufacturers in the sector (Mani 2004), and the dependence of the innovation system in software on multinational companies in Brazil (Stefanuto 2004).

The pattern of specialisation described in section 6.2 and re-examined in the case studies shows how these different types of organisation co-evolve as a result of a mixture of technical change, foreign direct investment and sectoral policies. It demonstrates that foreign companies, private research institutes and (to a smaller degree) private educational institutes become key nodes integrating disperse capabilities inside the quickly expanding software project network in Brazil. National companies have been less involved in software. Many technological institutes have diversified their development activities in order to cope with uncertainty in the demand. Changing needs from companies have resulted in making private research institutes the key to successful integration of disperse knowledge into complex product development networks.

The third question explores the speed of change and interdependence in the inter-organisational linkages of the knowledge networks. The examination of the stability and change of the knowledge network in different activities is important to understand how the technological capabilities are created and new sources of technology are explored. The analysis of the inter-organisational linkages has provided insights into how specific communities of practice emerge and change over time.

While the general technological specialisation of the sector has been relatively stable over time, the changes in the inter-organisational patterns in the sector were very intense. Significant knowledge was created in projects and at the same time a part of this knowledge was also lost when teams disbanded. In the short run (one-year time span), the knowledge network has been relatively stable (up to 88%) although technological change as well as discontinuities and modifications in the institutional framework may significantly impact the knowledge network. Between the first and last year of the sample - 1997 and 2003 respectively- less than 5% of the knowledge network was the same. Nevertheless, part of the knowledge has remained embedded in specific communities of practice.

The correlation between networks in different activities also shows that different types of knowledge bases require different types of inter-organisational channels limiting the possible knowledge flow to specific communities of practice. The decomposition of the knowledge network in different activities allows for the investigation of the characteristics of the superimposed inter-organizational networks involved in the innovation process and the complexities of their alignment in sectors. The analysis shows that knowledge networks are not homogenous structures as usually portrayed in most of the recent literature on the topic. They are formed by different superimposed and relatively independent communities of practice. There are also important interdependences between different activities, particularly in the network formed around multinational companies. The strong shift in the demand between middleware and software has resulted in an important interdependence between these two networks. The correlation between quality systems and developed capabilities also shows the importance of this activity during the catching-up process.

Therefore, an examination of the dynamics occurring in project-knowledge networks provides relevant insights into the dynamic in the sector. Because of the interest in exploiting a variety of opportunities and knowledge sources, inter-organisational linkages in enabling networks are volatile Developing networks are also volatile as the core companies could not sustain investments over time nor accumulate significant capabilities (although experimentation continues to happen). In the two developed networks, the instability seems to be mainly caused by the shifting demands from middleware to software.

The fourth question is related to the common organisational configurations emerging in the network between multinational companies and innovation systems. The research resulted in a taxonomy with 12 different configurations divided between SIS-centered (Technological Sponsorship, Technological pools, Sectoral programmes, Technological Consortia), MNC-centered (Local Products/Processes, Certification and technological audits, Offshoring R&D and Original Design Manufacturing) and integrated configurations (Global Mandates, Centres of Competence, Corporate venture, Technological scouting). Configurations differ significantly in terms of complexity.

The configuration of elements inside the network with the wider number of stakeholders will significantly promote or hinder the knowledge flow and technological accumulation to a specific number of participants. Ultimately, knowledge transfer requires that parties are willing to build knowledge-sharing routines, to strengthen their complementary resources/capabilities, to develop trust and effective coordination mechanisms (Dyer & Singh 1998). These mechanisms are costly, provoking uncertainty and risk and therefore are involved in bounded rationality.

From the analysis of key actors, it was possible to observe that SIS-centered configurations were more common in enabling networks, while MNC-centered configurations were more common in developing networks. In developed networks, there were a wider range of configurations, including integrated configurations. This classification contributes to the understanding of the links between the knowledge base of the innovative activities, organisation of the subsidiary and their technological partners and the structure of the network in the sector.

The fifth question explored how different stakeholders benefit from knowledge and financial flows in different configurations. It investigates and characterises the usual aims of different groups of stakeholders in different configurations. The results show that there is a subtle negotiated balance among different aims in the decentralised knowledge governance in sectors. Decentralised project-based knowledge networks are complex social networks involving a large number of stakeholders, usually with different aims. It shows that the aims of different actors are not necessarily the direct economic exploitation of the resulting innovation. In most cases, more indirect objectives such as capacity building, reputation (particularly inside the MNC, but also in the local market) and identification of talents are crucial reasons for supporting different innovation projects.

Very few configurations contributed widespread benefits for a wide number of actors. Most of the knowledge created in projects had specific aims that were defined inside the scope of the project although the knowledge created in specific projects may be codified and transferred to subsequent projects and become part of the organisational and inter-organisational learning (Nonaka & Takeuchi 1995).

It shows that the emerging structure of the knowledge network is susceptible to the influence of different stakeholder groups. Clearly, those technological partners (particularly private research institues) that managed over time to build those skills demanded by the main companies (mostly foreign) were those growing and reaping the benefits of the institutional framework. Clearly, the explicit and implicit aims of specific stakeholders in an individual set of projects may block the participation of other groups and reinforce path-dependency. Among others, universities and traditional public institutes have to redefine their niche role in the knowledge network focusing particularly on research, training and technological services.

The analysis of the cases also shows that many of these conflicts of interest in the network are not necessarily open. Passive selection of specific configurations and preference for specific stakeholders can have clearly negative effects on the sectoral dynamic. The rules for assigning benefits or the inclusion of a number of companies (through the association of their products to the tax incentives) and other organisations (through regulatory requirements, for instance) involves trade-offs that will influence the diversity creation (e.g. in the entrance of new members) and better allocation of existing resources (e.g. through the strengthening and consolidation of existing actors).

It was also important to observe that while the enabling networks tend to involve a large number of local stakeholders, the developing networks tend to be relatively concentrated among very few players. This is related to the strong use of MNC-centred configurations in developing networks. These connections with the multinational network are fundamental to expand the capabilities of the subsidiaries in core product and process technologies. In the enabling technologies, the interorganisational linkages are not so intense, but they are widespread, including a large number of local stakeholders. Finally, developed networks are governed by a complex network of configurations including integrated configurations, in addition to the other models.

Based on the above, it is possible to summarise some key results in terms of the general research question of this thesis. The results demonstrate how the knowledge flows (and their direction) depend on the alignment of interests among stakeholders. Emerging organisational configurations institutionalise specific practices developed in projects and therefore respond to a limited number of aims and stakeholders. In most of the configurations, there are variations in informal and contractual rules that influence the way knowledge may flow among partners. These variations usually are the result coming from the characteristics of the knowledge base and the evolving negotiation of interests and evolving practices among the different parts of the knowledge network. Therefore, examining the emerging configurations has been demonstrated to be an important element to investigate the alignments and misalignments occurring in the sector, and an important basis for discussing organisational strategies and policy interventions.

9.2. IMPLICATIONS FOR THE LITERATURE

The current literature examining the interaction between multinational companies and host country innovation systems relies almost exclusively on econometric measures to understand knowledge spillovers measured in terms of the possible economic outcomes. It is necessary however to recognize that the knowledge spillovers are ultimately the result of organisational mechanisms and institutional characteristics.

The analysis of the knowledge related links between multinational companies and host innovation systems provides a context of crucial importance for different streams of literature such as the analysis of interorganisational knowledge networks, the management and evolution of multinational companies and the analysis of national and sectoral innovation systems in developing countries.

9.2.1. In relation to the interorganisational knowledge networks

There are a number of contributions to a wide range of literature that discusses interorganizational knowledge networks. First, as reviewed by Provan, Fish and Sydow (2007), there are still very few empirical studies examining whole networks, particularly interorganisational business networks. Using project level date, it was possible to examine the longitudinal process in the network in the Brazilian ICT sector, a key sector in an important emerging economy.

There are also methodological contributions to the empirical exploration of interorganizational networks. This thesis suggests and applies a number of new methods for examining the specialisation and interdependency in knowledge networks inside sectors. Specialisation, differentiation and integration (interdependence) were demonstrated to be valuable dimensions in understanding the diffusion of tacit knowledge inside and among companies. A combination of traditional and non-traditional network properties provided key insights into the dynamic evolution of the network.

In addition, it shows that the combination of quantitative and qualitative methods is important to understand the governance and dynamics of the network development. In most of the literature on networks, the characteristics of individual nodes are overlooked. The complementary examination of key nodes and their main interactions extends the analysis beyond the boundaries of the quantifiable method. The combination of quantitative and qualitative methods for examining the network allows a deeper insight into the evolution of the network. The complementary qualitative analysis examines how the diffusion of knowledge is influenced by specific norms, practices and perspectives of core actors. It also allows us to understand how agents bend rules to their advantage along the dynamic development of the network (Dyer & Singh 1998; Knight 2002; Lane & Lubatkin 1998).

The analysis also provides a deep insight on how interorganizational networks are a source of learning for organizations. The social engagement in networks was recognised as the fundamental process by which individuals and organisations get to know what they know and by which they become who they are (Walker, Kogut & Shan 1997; Wenger 1999). This was evident in the cross analysis between quantitative and qualitative data. In addition, an important part of the knowledge is embedded in the specialised community in the form of tacit knowledge (Sapsed et al. 2002; Sydow & Staber 2002) and that could not be observed in the quantitative data. Therefore, quantitative and qualitative approaches provide complementary insights into the network evolution, and the way one could use an understanding of the networks to suggest interventions to promote these communities.

The analysis of the knowledge networks presented in this thesis reinforces the claim presented in the recent literature exploring interorganizational knowledge networks: Co-location does not seem to be enough for the transmission of knowledge (Boschma 2005; Cooke & Morgan 1998; Iammarino & McCann 2006). Specific inter-organisational mechanisms are necessary to allow local firms and institutions to acquire knowledge created in the multinational knowledge network. This is made evident by the importance of the emerging configurations in directing the flow of knowledge and financial resources in the network.

There is also a contribution to the literature that attempts to understand the dynamics of networks based on their underlying processes. The application of the concept of emerging configurations has demonstrated itself to be a useful tool to discuss the evolution of the network. Depending on successful performance perceived by stakeholders and general context, specific configurations may evolve into relatively stable patterns of relationships and be superimposed to previous configurations forming more complex organisations. This allows the development of theory on interorganisational networks that balance technological and social determinism in the evolutionary dynamic of the network. Based on evolutionary thinking, the emerging configurations allow for the identification of promising paths and potential lock-ins. Although it is clear that most of the cognitive complexity usually associated with individual routines was simplified in the constructs defined here as emerging configurations, the approach used has the advantage of allowing for greater comparability, something sought in the recent agenda related to the analysis of routines (Becker et al, 2005).

The comparison of the different knowledge networks formed by different innovative activites contributes to the line of research interested in understanding how the knowledge base influences the structure of the different networks. These results indicate that both the breath and depth of the definition for innovation projects significantly influences the kind of knowledge networks that emerge within sectors. By observing how companies behave in terms of conducting innovation in-house or collaborating with local technological partners, it is clear that some kinds of activities such as research and training tend to result in a wider number of ties, that would involve fewer resources. More often, other activities such as product and process development tend to be performed inside the organizations boundaries. In general, this pattern at the network level is in line with the behaviour observed in the research on innovation at the firm level (Tushman 1980). In addition, the analysis at firm level allowed us to identify important differences between the behaviour of the firm in less-developed networks as compared to its behaviour in more developed networks. Clearly, outsourcing of innovative activities was more often used in developed networks and this evolved into close relationships with increases in the overall level of investments in innovation. Thus, suggesting that the internal accumulation of technological capabilities and consequent differentiation inside the network is a important component of the overall network evolution (Gulati and Gargiulo, 1999).

Finally, the combination of qualitative analysis also provides a deeper understanding of the mechanisms by which the micro-level choices such as the type of activities influence the overall macro-level network structure. Contributing to a structuration theory, it is possible to observe the following pattern of co-evolution between the types of activities performed by agenda, the organizational configurations and the overall structure of the knowledge network. First, there is a connection between specific types of activities and the number of organizational configurations usually emerging from these activities. In turn, these emerging configurations influence (and are influenced by) the characteristics of the innovation network. For instance, research and training activities tend to be developed in organizational configurations centered on the sectoral innovation system (e.g. sponsored initiatives, suppliers, sectoral programmes and technological consortia). These activities - led by a wide number of sectoral organizations - tend to involve relatively small contributions from the core companies that engage in project swith a relative disperse number of partners. Development projects, particularly in less developed networks, tend to evolve in MNC-centred configurations. As more and more investments in product and process development are executed inside the sector, integrative configurations start to emerge, increasing the number of outsource innovative activities and changing the characteristics of the overall network. These macro-micro mechanisms are clearly in line with the structuration theory and reinforce the importance of understanding the underlying routines as a key to understanding the economic evolution.

9.2.2. In relation to the evolution of multinational companies

There is no reason to believe that knowledge would always flow from headquarters to the subsidiary, and consequently to the host developing country (Bell & Marin 2005). The recent literature on the multinational companies has pointed out that there are a number of inter-organisational configurations that characterise the knowledge and financial flows.

The taxonomy of the usual underlying combination of structure and strategy in R&D activities has provided interesting insights into the evolution of multinational companies. Examining the usual interaction patterns among R&D laboratories and different actors in innovation projects has proved to be a useful way to describe the structural alternatives available for the organisation of innovation in a specific context. Mapping the common knowledge and monetary flows in each configuration has contributed to the task of distinguishing how different groups of stakeholders are involved in individual projects and has aided the understanding of the complexity required for developing complex governance structures.

The project-based taxonomy for knowledge flows between multinational companies and sectoral innovation systems presented here is, in a larger context, compatible with some previous classifications of roles of R&D laboratories in subsidiaries. For instance, the MNC-centered configurations and SIS-centered configurations are similar to asset augmentation and asset exploitation in R&D units (Kuemmerle 1997, Cantwell 1995). It adds to the current literature on international management as the approach adopted here allows for the deeper exploration of a wider number of configurations than usually are attributed to R&D subsidiaries. This approach coincides with Kogut's suggestion that simplified typologies of the expected role of subsidiaries provided by the international management literature have done little to advance our understanding about the process by which subsidiaries evolve (Kogut et al. 2002).

The examination of the different configurations contributes to the dynamic analysis of the subsidiary development (Birkinshaw and Hood 1998). It shows that subsidiary development is not a linear process of accumulation of technological capabilities. Achieving more complex configurations seems to be a result of historical combinations between configurations over time. Non-linear attempts in unusual innovation projects introduce crucial opportunities for the long term development of the subsidiaries even when they are small in size as compared to projects in established configurations.

Subsidiaries test different organisational characteristics in specific innovation projects, usually related to an entrepreneurial action occurring at a non-particular time. Experimentation with different configurations seems to be a necessary condition as each one of the different configurations has their own challenge to achieve sustainability over time. Hence, the concept of punctuated equilibrium (Egelhoff 1999; Romanelli & Tushman; Van de Ven & Poole 1995) seems to be an important element to be investigated in the subsidiary development.

The results also support the idea that the most significant types of learning will just occur where organisations make intentional use of their relational structure and shared coding schemes to enhance the transfer and communication of new skills and capabilities (Kogut et al. 2002; Kogut & Zander 2003; Zander & Kogut 1995). Therefore, the development of taxonomy of knowledge flows between the multinational and national networks is important as knowledge flows are contingent on these organisational configurations.

The detailed exploration has identified the different patterns emerging from organisational configurations and encouraged an in-depth discussion of the sustainability and stability of the knowledge networks. The study shows that there are a number of complex configurations that interconnect national and international knowledge networks. It also points to the increasing importance of understanding the objectives of different actors and different forms of governance mechanisms that would allow for the identification and pursuit of complementary aims.

Although, R&D laboratories in subsidiaries are usually assumed to be key elements in promoting the flow of knowledge between the multinational sources of technology and the local industry, most of the activities tend to be organised around configurations that separately engage national technological partners, different subsidiary functions and players in the multinational company. This supports the idea that the subsidiary contains internal isolation mechanisms (Solvell et al. 1998) that need to be understood. In a number of cases, interorganisational linkages with both national and international partners do exist, but they are composed of different groups of people specialised in attending to different demands. In other cases, R&D departments may develop strong international linkages and, at the same time, have no connections even with other departments inside the subsidiary. Even when both organisational linkages exist, subsidiaries can also use internal mechanisms to passively or actively deter knowledge from flowing through different networks.

9.2.3. In relation to the literature on sectoral innovation systems

The literature on sectoral innovation systems, particularly in developing countries, has just recently started to acknowledge the need for longitudinal measurement of the underlying knowledge networks in sectors. An exclusive focus on the accumulation of capabilities tends to neglect the division of innovative labour occurring between the firms and their technological partners in the same sector. The analysis of networks in developing countries adds to the usual 'technological ladder' approach to investigate the underlying principle of the formation of dynamic comparative advantage sectors in developing countries. The examination of the structure of the networks in developing countries contributes to this literature and intends to avoid a linear definition of the accumulation of technological capabilities by explicitly discussing the different functions involved in the sectoral innovation systems in developing countries.

This analysis contributes to the literature exploring the concept of network alignment at a project level. More than simply offering recognition of the specific roles in the multinational hierarchy, this analysis examines issues of interactive learning and dynamic evolution through the interaction with the multinational network and host innovation system which prove to be essential in determining the direction and magnitude of the knowledge flows. The analysis of the underlying motivations, aims and benefits of different stakeholders in engaging in a large variety of collaborative activities shed some light onto the knowledge flows that occur between multinational companies and host innovation systems.

In particular, the analysis makes explicit some of the conflicting interests in the interaction between multinational companies and sectoral innovation systems in developing countries. Coordination between the interests of multinational companies and the sectoral innovation system is fundamental. However, rather than a unique model, the analysis of the underlying configurations allows for appreciation of the diversity of bottom-up models in sectors. It shows the diversity and development of the governance mechanisms necessary in modern catching-up processes. Balancing short and long-run sustainability between the investments in complex networks would involve a constant process of institutional and organisational learning. In this process of planning and coordinating interventions (or non interventions) in sectors, it is necessary to take into account the characteristics and limitations of the existing knowledge activities and the technological opportunities open to the industry.

The analysis also shows the important interdependencies between different "systems" in the sectoral system. This analysis of sectoral systems based on a wider range of aims related to the knowledge network is a relevant contribution, as traditionally, the literature on innovation has restricted successful innovation to a commercial perspective of the company that promoted the innovation project and introduced it to the market (Rothwell et al. 1993). Under a developmental perspective, it is evident that other factors must also be included. Certainly, what is considered a successful project for a university differs from the requirements of a multinational company. Naturally, commercial success remains among the most important measures, but it is by no means the only one. The project-level analysis suggests the need for constant alignment between the aims of individual organisations and the aims of the network as a whole. On one hand, given the complexity of the innovation process, specific projects will address the aims of a reduced number of stakeholders while, sectoral aims usually require that a wider number of stakeholders are considered (or aligned). This alignment may occur by interventionist or *laissez-faire* policies and they need to be assessed opportunistically. The measurement of the current characteristics and identification of recurrent underlying configurations can provide a basis for the institutional learning process.

By examining the knowledge network under the Brazilian ICT Law as a whole, it was possible to observe a factor that is far less explored in this literature, that is, the interdependency between sectoral sytems such as those related to computer, telecom infrastructure, mobile, components and digital television. Particularly relevant in this case is the major shift in the investments from middleware to software. It shows a case where innovation projects were the key ways used by companies to change their core capabilities in a relatively short period of time.

The growth of the capabilities related to software within the core nodes of the actors involved in middleware technologies shows that the changes in the portfolio of projects of multinational companies and reorganisation of teams permitted this shift. Therefore, the direction of the knowledge flows also depends on the organisational learning occurring after the innovation projects end. The ability for different organisations to incorporate this tacit knowledge after projects are concluded and teams are disbanded is a crucial determinant of the long-term direction of the knowledge flows in the sector. Indeed, in some cases, the knowledge flows between organisations occurred when the projects finished and human resources were relocated. When specific configurations failed, there was a need to reorganise existing capabilities into new situations.

Naturally, this is not to say that the high volatility of the knowledge network was beneficial to the sectoral innovation system. In general, the result of the dismantling of a highly differentiated group is significantly dysfunctional given the tacitness of the activities involved. To create a group that operates efficiently in a sustainable configuration involves considerable resources, strategic vision and time. Most of these transitions between different configurations involve a significant level of uncertainty and may face considerable inertia from different stakeholder groups. A successful innovation system has a considerably stable accumulation of technological capabilities, rather than very strong "creative destruction" (Cantwell 2001). The ability of different organisations and the wider network to adapt and grow beyond different projects needed to be considered as a crucial determinant of the direction of the knowledge flows in sectors.

These findings have important implications for those involved in the institutional design of sectoral policies. Transferring specific institutions from developed countries into developing economies may be insufficient or even distort and hinder the cohesion and alignment of the knowledge networks in sectors. Specific strategies and policies should be adapted to the specific characteristics of the knowledge network. Some of these implications are discussed in the next section.

9.3. IMPLICATIONS FOR POLICY AND MANAGEMENT

Understanding the role of specific organisations and their knowledge-related interactions has been the key challenge for innovation management and policy. This thesis contributed to the empirical literature on sectoral innovation systems exploring the underlying structure and dynamics of the knowledge network formed around multinational companies in innovation projects. The analysis aims to contribute elements for those involved in the institutional designing and monitoring of sectoral policies.

A project-based framework for analysing the co-evolution of technologies, organisations and institutions at the sectoral level is still an under explored method for the analysis of the sectoral policies. This thesis advances methods in this direction using a project-level framework to identify emerging configurations between the knowledge base and flows among stakeholders in multinational and host innovation systems.

The analysis suggests that the formation of specific governance structures and inter-organisational linkages is the basis that defines the occurrence and direction of these spillovers. Through time, compromise and adjustment between different interests inside and outside the network should allow for the identification of endogenous growth opportunities.

Therefore, although R&D incentives are usually created to promote grassroots innovative activities in companies, a deeper analysis of the organisational networks formed by innovation projects can be used to support better coordination at sectoral levels and to help in the recognition of general dynamics as well as encourage important individual initiatives.

In chapter 8, the dynamics of different trajectories were explored and possible strategies and interventions for promoting the knowledge networks in the sector were discussed. In addition to these recommendations, there are also some general important lessons to be derived from this experience in the Brazilian ICT sector for the multinational companies, system integrators and sectoral policies.

9.3.1. The challenges for the creation of adequate incentives to innovation in subsidiaries

Subsidiaries of multinational companies played a fundamental role in the accumulation of technological capabilities in the Brazilian ICT sector during the period. Subsidiaries were crucial in creating internalised learning mechanisms during the early stages of the catching-up process. There were also a number of initiatives in subsidiaries to improve their quality systems and certification, offshore R&D activities and/or to provide ODM products to local clients.

It is clear however that their integration with existing networks and the diffusion of knowledge into existing social structures was not a homogeneous process. Most of the first tier of multinational companies attempted to obtain attributions in the global knowledge network. However they were not able to sustain large investments in a number of technologies. In the Brazilian ICT sector, so far, the group of foreign companies (as indeed national companies) did not manage to develop large teams working in semiconductors, production process and hardware technologies. Although there were important initiatives, each one of the initiatives tended to be highly internalised and there was very little attempt to articulate and integrate disperse technological capabilities.

In software and middleware technologies, R&D offshoring activities tended to evolve into more complex relationships inside the multinational companies and within the host innovation system. The configurations in the developed networks show the tension between integration and specialisation inside the multinational network. On one hand, some R&D groups integrated deeply into specialised niches and differentiated inside the company's technology. Integrating into global networks was critical in determining the learning process from international sources of knowledge and from the nature of the capabilities accumulated in the sector. By integrating their services inside the corporation, they expanded the sustainability of the investments in R&D at the same time that they renounced autonomy over the investments. Reduced autonomy was connected with a certain reduction on the number of technological partners for reasons of scale and confidentiality.

The sustainability of the groups was strongly influenced by their constant ability to identify new niches in the multinational network. In the Brazilian case, general growth opportunities however remained limited as the subsidiaries were actually squeezed in the competition with other subsidiaries, particularly in China, India, and Russia. They also used local corporate venture capital and/or differentiation of their core competence from other units. Subsidiary managers need to constantly balance different configurations, indeed even superimposing different configurations to sustain their capabilities.

It is also important to note that the most adequate configurations change over time. For instance, during the last few years, given the reorganisation of the production process around large contract manufacturers, opportunities for scale and scope around the contract-manufacturers are emerging in an ODM configuration and accumulating considerable capabilities in hardware. Also, an endogenous process of diversification occurred inside the network while the opportunities shifted from middleware to software along the examined period. Particularly inside the MNCs, many project-based arrangements were not sustainable over time.

Structural changes in the organisation of multinational companies provided some opportunities for subsidiary managers to exploit the windows of opportunity resulting from the increasingly dynamic integration of the global economy. Consolidating new routines, disruption and reconfiguration were fundamental parts of the sustainability of the subsidiary development (i.e. balancing exploitation of existing knwoeldge and exploration of new knowledge).

The institutional framework provided an important organisational slack for subsidiary development in order to pursuit these opportunities. Indeed, some of them made impressive progress in terms of accumulation of technological capabilities and repositioning inside the global network. The results however varied substantially across the sample showing the disadvantages of horizontal incentives. While the stability of the institutional framework was fundamental to promote the long-term accumulation of technological capabilities in the subsidiaries, there were many situations where the organic growth proved to be unsustainable.

Some warnings are important here. It is likely that supporting R&D groups which are isolated from the sectoral innovation system may not result in substantial benefits to the host country. It is also evident that policies which support R&D groups in areas with low potential and low interest from managers are very wasteful undertakings. Complementary targeted mechanisms may need to be developed in order to adjust incentives and sustain the network alignment.

9.3.2. The challenges for the sustainability of private research institutes

Clearly, the most direct result of the sectoral policy is that some technological partners, mainly private research institutes, became the *de facto* high-tech system integrators. Given its efficiency and scale, these private research institutes were even competitive in the open market. Usually, private research institutes operate as project-based organisations, integrating and articulating disperse capabilities in the sector.

However, they became highly dependent on the incentives to sustain their capabilities and growth. The private research institutes became the receptors of a disproportional part of the total investments by partners inside the ICT Law. It is very unlikely that other private institutes will be able to emerge in the already competitive “market” for R&D projects. In addition, given its short term outcome, they may drag resources out of riskier activities in other trajectories and from other agents such as universities and centres of research.

Their role in the successful development of the software knowledge network is impressive, but further modification seems to be required if one expects to achieve sustainable growth and view the reappearance of opportunities for the emergance of new actors and trajectories through the resources provided inside the framework. If at any point the subsidies will be phased out (as it is now expected for 2017), the issue of the sustainability of private research institutes must be addressed. The private research institutes are much more susceptible to the changes in the legislation than any other actor in the system.

There are still inadequacies on the corporate governance, such as the impossibility of distributing dividends; most certainly this inhibits private investments in different technological partners. The existing lack of ownership may breed contempt among current managers and stakeholders with residual power. Specific groups may influence governance and create inefficiencies. In addition, the incentives of regulation would increasingly substitute for (or even exclude) private investments in these organisations.

In addition, they also may have reduced their internal incentive to maximise their performance (although there were certainly many entrepreneurial private research institutes among the most successful groups). In some cases, it was possible to observe that rigid regulations may have had an important adverse impact on the ability of organisations to respond to changing environments. A plan to promote corporatisation would be necessary for individual institutes and for the sectoral dynamic in the long-run.

The existing framework derived from tax obligations provided them with a stronger source of income than that which could be expected from private investors. However, rather than indiscriminating subsidies or calls for proposals that focused on academic criteria, traditional business-led returns on investments could be more efficient in targeting short-term technological opportunities and could be more connected with their business-driven nature. At the same time, a process of progressively sharing risks with local organisations in these investments opportunities could open a different path of consolidation and competition in national and international markets.

9.3.3. Failures and successes in the coordination of enabling networks

The fact that companies preferred to outsource innovative activities such as training, research and technological services does not mean that they were simple market-mediated transactions. There is clearly a need for coordination, regulation and governance in these areas of sectoral concern.

Indeed, specific forms of governance were fundamental in all these activities, for instance, to certify the quality of training, technological services, complementary funding to research, etc. Innovative projects such as technological services, training and research activities and research were indeed conducted with a large number of technological partners and were usually associated with the idea of 'sectoral goods'.

The attribution of the responsibility to individual firms for the initial investments in specific fields has brought up a number of difficulties in terms of coordination and agency. The number of sectoral public projects sponsored by individual companies or spontaneous resource sharing tends to be suboptimal under a social perspective (in this sense, following the usual rational for public intervention). Initial investments to establish basic infrastructure in new technologies tended to be very high and the appropriation for the investments were not granted. Following the expected behaviour, individual companies tended to postpone the investments in public projects or avoided them completely.

Even so, it was observed that the investments in these areas, even when decided by private companies, did seem to have important spillover effects in the system. To a reasonable extent, individual companies in the sector have sponsored large sectoral projects (such as the national network of high performance computers, changes in the national curriculum for engineers, acquisition of test equipment, and so on).

However, probably the most important 'sectoral good' was the creation of a market in specific scientific training, technological services and even applied research. These enabling activities could be reasonably specified by contracts and companies that acquired these services from established technological and educational institutes. Although first movers in specific areas had to incur higher costs, the availability of local providers reduced the costs in these enabling activities for other companies starting in similar technological areas.

Naturally, considerable investments from private multinational companies tended to focus on the areas of their strategic interest. Following a flagship model (Rugman 1997), multinational companies are particularly able to bargain their position and interests in relation to different technological partners. Evidently, their interests in developing specific capabilities in partners may coincide with developmental goals and the creation of 'sectoral goods" in many of the enabling activities.

However, the local coordination of resources and capabilities will not happen naturally. They require a considerable effort on the part of a large number of intermediate organisations such as agencies, educational and technological institutes. The most successful organisations were a result of well-crafted alliances reached through a considerable amount of time and effort devoted to trust building among competing interests.

These governance structures should be able to provide not just random support to bottom-up initiatives based on generic academic criteria but provide a reasonable realistic and coherent vision to the development of the sectoral capabilities. A common vision will be feasible only if it is shared and if it engages a wide number of relevant organisations in the sector. For instance, the lack of convergence between the aims of multinational companies (key sponsors) with the primary aims of the sectoral programmes is clearly one of the main reasons for its relative failure in some policies promoting exports of small software companies, while achieving success in areas such as improvement of software quality.

Rather than listing a specific set of attributes and roles assigned to multinational companies and host country technological and educational institutes, a constant examination of complementarities, lock-ins and opportunities inside these enabling knowledge networks is required. This can only be done by diversity in forms of governance, combining public and private investments.

On a sectoral level, structuring programmes and regulatory agencies seems to be particularly important to guarantee adequate levels of investments in innovation-related infrastructure, training and metrology. Ideally the governance should ensure that other relevant groups of stakeholders are included in the decision-making process. In coordinating these enabling networks, one must not ignore the risk of favouring specific established groups over possible newcomers and predetermining the capture of resources that in practice substitute for private investments.

Both large companies and research institutes started to create their own associations in order to articulate their demands and to make sure that their voices would be heard by the governmental agencies (respectively a R&D group inside the ABINEE and an association of private research institutes). This is certainly an improvement in the coordination of the system. The organisational basis for the public-private debate seems to be maturing and it should be the focus of constant reflection.

Governance in these enabling networks should be a type of encouragement as a form of interactive policy learning is essential. There is however a long way to go towards a really open and effective interaction of the centralised and decentralised governance structures. The alignment of the sectoral aims is subject to dynamic renegotiation of roles and the strength of different stakeholders. I t should allow space for individual agency in different directions. A careful engagement with a wide number of stakeholders in enabling networks provides a way to promote long-term alignment and sustainability of the different product development activities.

9.4. BOUNDARIES AND LIMITATIONS OF THE RESEARCH

It is also necessary to set the limits of the scope of the research findings. First of all, the generalisation of the findings needs to be considered with care as the cases involved are limited to sectoral and historical circumstances circumscribing this research. There is a certain 'uniqueness' in terms of the institutional setting also limiting the extent to which each of the results observed in this study can be transferred to other circumstances, sectors or countries.

However, deconstructing each one of the configurations by its activities and investigating common characteristics in a multi-case setting could be considered as an adequate basis for the development of a general taxonomy, at least in the same sector. These basic building blocks highlight general principles in the organisation of the interaction between multinational companies and innovation systems in developing countries that could be expanded and tested in other contexts.

As discussed in the sampling method, this study uses a diversity of the organisational arrangements involved, therefore, arguing that they provide an adequate basis for building theories based on case-studies (Eisenhardt 1989). This diversity is however constrained inside multinational companies in the ICT sector with considerable manufacturing capabilities. This limits the use of the general characteristics observed here in other sectors.

There is an extensive use of secondary data declared by companies and technological partners under the Brazilian ICT Law. Part of the study is strongly based on the structure used in the procedures defined by the regulatory body (MCT/SEPIN). Although the data on the innovation projects was audited by public servants, there might be ambiguity in the way companies and institutions declared the costs of different types of activities.

The methods used for the identification of the patterns of configurations in the sector are essentially qualitative and the number and variety of companies did not use statistic treatments to achieve the obtained answers. Although most of the usual configurations in the different networks were probably identified and discussed in the cases, there are natural shortcomings derived from the limited number of interviews, especially as they were focused on large multinational companies and key technological partners (mainly private research institutes).

Among the most important limitations is the fact that many R&D groups were disbanded before the fieldwork was complete and therefore they could not be interviewed. There are also limitations in the interviewees' memory and attribution bias (Dougherty 1992). Some of the questions asked may have been considered sensitive by managers. Interviews were also susceptible to misinterpretation or unconscious influence by the researcher on the interviewee.

Nevertheless, a number of specific strategies were used to reduce the influence of the specific institutional setting provided by the regulatory framework. Triangulation between the answers provided and the secondary data collected under the Brazilian ICT Law procedures was used to mitigate some of the key limitations (Jick 1979).

Although the network is deeply influenced by the context of the tax regime which was present between 1997 and 2003, there is no reason to constrain the utilised methods to this unique source of funding. A project level analysis of the knowledge networks could encompass other forms of funding organised by projects, a common modality in grants or other forms of support for innovation. As other sources of funding emerge (e.g. sectoral funds, local agencies, etc), the analysis of these networks could help the development of realistic sectoral strategies in the different developmental aims.

9.5. QUESTIONS FOR FURTHER RESEARCH

If we expect to understand the formation of the knowledge systems in developing countries, we must go beyond the analysis and consequent evaluation of the usual nationalistic and politically charged formal programmes or ideologically influenced liberalizing reforms. We must thus take hold of the more complex underlying process which defines the existence of a system, that is, the set of interactions between private and public, domestic and foreign economic agents. Developing databases of the interaction at project level may provide good insights in this direction.

It was clear in the analysis that compromise and adjustment between different public and private interests should allow for the identification of endogenous growth opportunities. The political strength of specific stakeholders may block the participation of other groups, resulting in a reinforcement of specific path-dependencies. Dynamic methods for measuring the process of accumulation and the diffusion of knowledge could help the "management of lock-ins" in the decentralised knowledge networks. A comprehensive analysis of these project-based networks could help in developing more adequate sectoral strategies in the different developmental aims.

The exploratory taxonomy of the configurations between multinational companies and sectoral innovation systems in a specific sector and historical context still faces a number of limitations. At the same time, most of the configurations identified here are not new in the literature and most of them have extensive documentation in both international management and organisation of innovation literature. The contribution of this research is the attempt to provide a project-level comparative framework for the analysis of the organisation of innovation that should be validated, adapted and expanded in different sectors and contexts. Studies combining quantitative approaches that examine the structure of the interaction in project-based networks would also be an important instrument in the unraveling and validation of the role of different configurations in the diffusion of knowledge amongst the sectors.

A project-level analysis of sectoral systems raises theoretical and practical lines of enquiry that remain largely open. For instance, how do individual actors contribute to the vitality of the knowledge networks? How could changes in the rules promote a better allocation of resources in the decentralised network? Would a rule-based allocation, a discretionary allocation or a combination of both improve the long term processes of variety in the creation and selection inside the decentralised network? What kind of interventions (or non- interventions) should be carried out in different stages of the development of the knowledge networks? What mechanisms should be combined in order to promote wider knowledge spillovers, stronger growth, and sustainability in the networks? How is the knowledge network related to the mobility of skilled workers in the sector? How is ICT changing the balance between local and virtual communities in R&D activities? Further research using agent-based modelling, geographic information, labour market, and international social networks could indeed provide a useful set of methodological tools to attempt to answer these questions and further develop the management of the knowledge networks.

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ANNEX 1 – MAP OF VARIABLES IN THE SEPIN/MCT DATABASE

This annex provides an overview of the data collected during fieldwork. It contains (1) the map of variables in the database constructed, (2) the main topics discussed during the interview and (3) the preliminary outline of the results chapter.

Table	**Fields**
Organisation*	Company (Institute), Year, Mission of R&D, Lab, Organisational structure, Imports, Exports, Size (employees), Turnover in ICT products, Investments in R&D
Projects *	Company, Year, Partnership, Title, Description/Motive, Costs in different categories, Classification 1, Classification 2
Products	Company, Year, NCM, Product description, Turnover
Transactions*	Company, Year, Project, Partner, Value, Classification 3, Classification 4
People **	Organisation, Year, Employee, Project, Cost, Function, Number of Hours
Travel**	Organisation, Year, Project, Cost, Destination
Location**	Name, Type, State, City

* data largely used in this research

** data used in this research just for basic descriptive purposes

ANNEX 2 - INTERVIEW PROTOCOL - QUESTIONNAIRE

A - VERSION USED WITH SUBSIDIARIES (TRANSLATED TO ENGLISH)

Identification (Name: / Position: / Department:/ Time in the organisation:/)

1 –Innovation projects

a) Please identify the key projects developed and competences created (ex. Labs and R&D teams) in the subsidiary. (The researcher completed elements in the following table).

Period	Project (or group of projects)	Target market	General Strategy/ (aim)	Investments (HQ)	Number of employees involved (postgraduate)	Number of employees 3 years ago	Trends -- decline ++ growth 0 stable

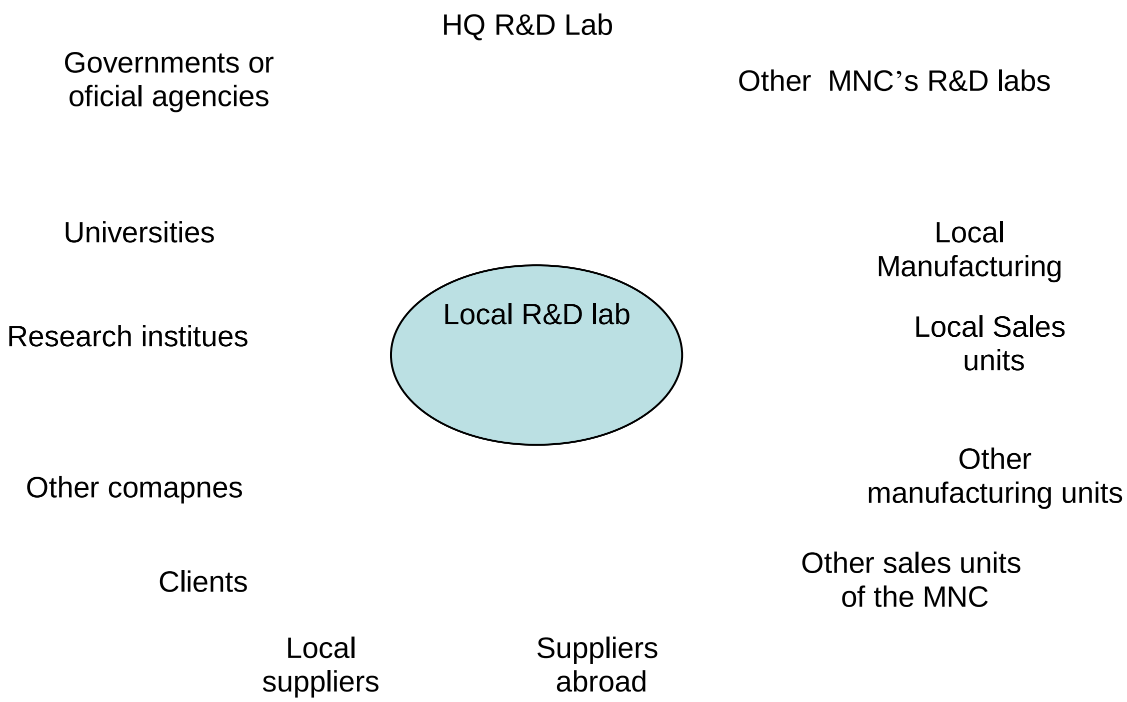
b) Please explain the main objective of the project for your organisation and others involved.

c) Please indicate the target market, estimated investments, number of employees involved in this line of projects, the trend in the last three years, and towards the future

d) What are the main results obtained?

2 – Knowledge network

Please identify the general characteristics of the knowledge network based on a diagram showing the subsidiary's R&D lab and a range of possible internal and external organisations.



a) Please indicate the partners connecting them with a line,

b) Please indicate the intensity of the interaction according to the following scale. (1- (low) ocasional, 2- (medium) about once a month, 3 - (high) weekly interaction)

c) Please indicate the direction of the flow of knowledge in this interaction (inwards if this is a source of knowledge, outwards if the external organisation receives the benefits from the knowledge generated in the lab. The options are not mutually exclusive)

3 – Organisational configurations

Open questions:

a) Which are the main elements of the organisation of the R&D activities inside the subsidiary? Please describe the process of innovation management developed by the subsidiary/ institute. Which are the key challenges? What did not work?

b) Which are the main elements of the organisation of the R&D activities linking the subsidiary and the multinational network? Please describe the process of innovation management in the interaction with the multinational company. Which are the key challenges? What did not work?

c) Which are the main elements of the organisation of the R&D activities in relation to the technological partners? Indicate the main characteristics of the selection (and maintainance) of R&D partners. Which processes have been developed in these collaborative activties? Which are the key challenges? What did not work?

Closed questions (used mainly to gather additional details on the characteristics of the subsidiary):

a) Mission of the R&D activities, In order to identify between asset-augmenting and asset-exploiting, the interviewees were asked to estimate the percentage of their R&D activities allocated to experimental or theoretical work undertaken to create or acquire new knowledge that the company considers important for future products, versus the systemic work based on existing knowledge inside the company and directed to the production of new products in immediate future or adapting existing products.

b) Interdependency of their activities with the Multinational and local R&D partners - interviewees were asked to estimate the percentage of their R&D activities received from other units and the percentage outsourced to external units.

c) Autonomy of the R&D unit - the interviewees were asked to identify on a scale, the importance of the subsidiary or the HQ in defining: the overall direction of the R&D effort, which new projects to pursue, documentation standards and norms, and the R&D budget.

d) Status of the subsidiary - interviewees identified on a five-item scale, the degree to which they agreed with the following statements, based on Birkinshaw (1996): Parent company R&D managers are confident that the subsidiary will achieve what it sets out to do; the subsidiary's capabilities are typically well understood by the parent company managers; the credibility of subsidiary top management is high.

e) Existence and participation in an internal market for projects - interviewees identified on a five-item scale, the degree to which they agree with the following statements: projects are contracted by divisions (in opposition to fixed tax is paid by divisions); there is choice of R&D Suppliers for Business Units; for any given R&D project there are several sites that could potentially undertake the work; R&D work is sometimes moved between sites as a result of performance differences between sites.

f) Organisational inertia to initiatives undertaken by the subsidiary - interviewees identified on a five-item scale, if it is common to face: requests from HQ for greater justification; Lack of recognition of new products developed by other units; delay/disinterest for projects with other units; Rejection by corporate management on grounds that initiative did not address strategic priorities for the corporation.

g) Changes over time - interviewees identified in a five-item scale, whether there were significant increases or decreases in the level of interdependency, autonomy, status, competition in the internal markets and organisational inertia in the last three years. They were also asked whether the overall mission of the subsdiary R&D activites are moving towards a exploration of existing knowledge in the multinational, or identification of new knowledge in the host country.

B - VERSION USED WITH TECHONOLOGICAL PARTNERS - TRANSLATED TO ENGLISH

Identification (Name: / Position: / Department:/ Time in the organisation:/)

1 –Innovation projects

a) Please identify the key projects developed and competences created (ex. Labs and R&D teams) in the institute. The researcher completed elements in the following table.

Period	Project (or group of projects)	General Strategy/ (aim)	Target market	Investments (HQ)	Number of employees involved (postgraduate)	Number of employees 3 years ago	Trends -- decline ++ growth 0 stable

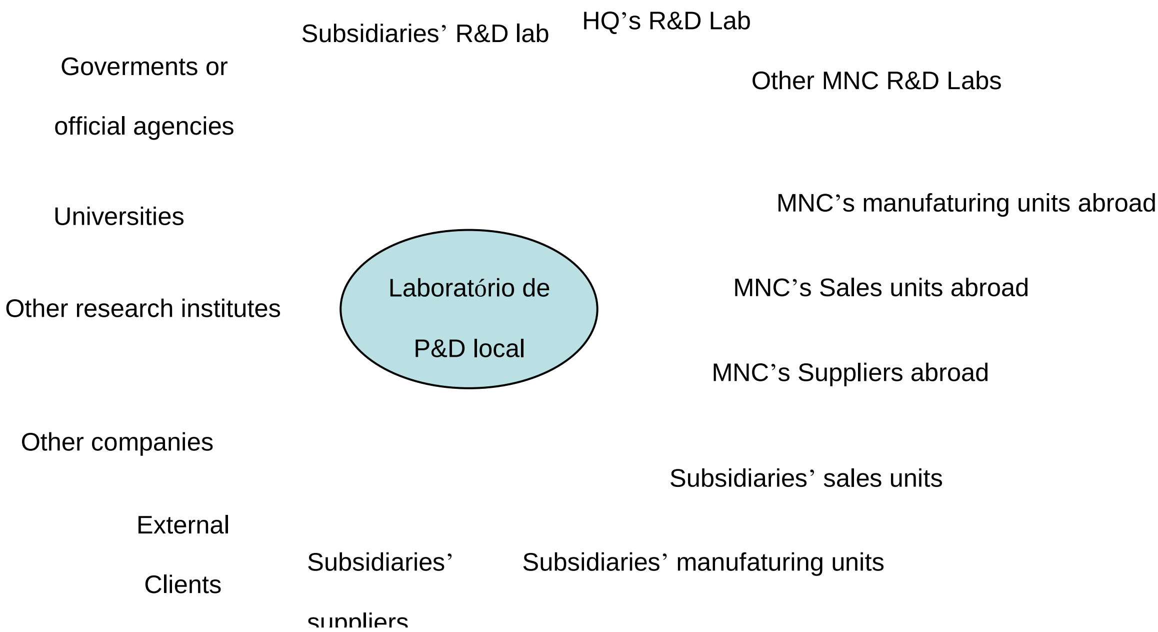
b) Please explain the main objective of the project for your organisation and others involved.

c) Please indicate the target market, estimated investments, number of employees involved in this line of projects, the trend in the last three years, and towards the future

d) What are the main results obtained?

2 – Knowledge network

Please identify the general characteristics of the knowledge network based on a diagram showing the institute and a range of possible internal and external organisations.



a) Please indicate the partners connecting them with a line,

b) Please indicate the intensity of the interaction according to the following scale. (1- (low) ocasional, 2- (medium) about once a month, 3 - (high) weekly interaction)

c) Please indicate the direction of the flow of knowledge in this interaction (inwards if this is a source of knowledge, outwards if the external organisation receives the benefits from the knowledge generated in the lab / the options are not mutually exclusive)

3 – Organisational configurations

Open questions:

a) Which are the main elements of the organisation of the R&D activities inside the institute? Please describe the process of innovation management developed by the institute. Which are the key challenges? What did not work?

b) Which are the main elements of the organisation of the R&D activities linking the institute and the multinational company(ies)? Please describe the process of innovation management in the interaction with the multinational company(ies). Which are the key challenges? What did not work?

c) Which are the main elements of the organisation of the R&D activities in relation to other companies? Indicate the main characteristics of the selection (and maintainance) of R&D partners. Which processes have been developed in these collaborative activties? Which are the key challenges? What did not work?

Complementary closed questions (used mainly to gather additional details on the characteristics of the instute):

a) Mission of the R&D activities, In order to identify between asset-augmenting and asset-exploiting, the interviewees were asked to estimate the percentage of their R&D activities allocated to experimental or theoretical work undertaken to create or acquire new knowledge that the company considers important for future products, versus the systemic work based on existing knowledge inside the company and directed to the production of new products in the immediate future or to the adaption of existing products.

b) Interdependency of their activities with the Multinational and local R&D partners - interviewees were asked to estimate the percentage of their R&D activities involving the main multinational, the percentage of their R&D activities with other companies and the percentage outsourced to external units.

c) Autonomy of the institute - the interviewees were asked to identify on a five item scale the importance of the main subsidiary (the client of the institute) in defining: the overall direction of the R&D effort, which new projects to pursue, documentation standards and norms, and the R&D budget.

d) Socialisation – During the last year approximately how many times did you or your technical staff work on projects with similar institutes or universities. How many people were involved in job rotation? Have project managers worked in the client companies? Have project managers worked in other institutes? Have project managers participated in capacity building programmes with other institutes? Do companies participate on the administration board of the institute? Does the institute participate on the sectoral board (CATI)?

e) Status of the institute - interviewees identified in a five-item scale, the degree to which they agree with the following statements, adapted from Birkinshaw (1996): The services provided by the institute are well understood by the companies in the sector; the institute's capabilities are recognised as a international centre of reference; the credibility of the institute's top management is high in relation to clients.

f) Corporate governance - interviewees identified in a five-item scale, the degree to which they agree with the following statements, the institute has clearly defined processes for (i) the association and maintanece of new associates from private sector, (ii) engagement of associates in decision-making and conflict resolution among associates, (iii) information flow among associate members, (iv) search and coordination of knowledge developed by assocated members (v) negotiation of contract and intellectual property (vi) public annual reports with financial statements.

g) Competition among institutes, - interviewees identified in a five-item scale, the degree to which they agree with the following statements, (i) projects are contracted as a whole by companies (as opposed to payment for human resources hours) (ii) the companies have a wide choice of R&D suppliers (iii) for any given project, there are many different places where the work can be conducted, (iv) the R&D work is sometimes transferred to other institutes as a result of differences in performance.

h) Changes over time - interviewees identified in a five-item scale, whether there were significant increases or decreases in the level of interdependency, autonomy, socialisation, status, sistematisation of the corporate governance and competition among institutes in the last three years. They were also asked whether the overall mission of the subsdiary R&D activites is moving towards a exploration of existing knowledge or identification of new knowledge.

C -ORIGINAL PROTOCOL USED FOR SUBSIDIARIES, IN PORTUGUESE

Identificação

Nome:
Cargo:
Departamento:
Tempo de casa:

1 - PRINCIPAIS PROJETOS DE INOVAÇÃO

a) Por favor, cite as principais projetos e competências criadas (ex. laboratórios ou equipes de P&D) na/pela subsidiária e período onde elas foram construídas.

Datas	Competências tecnológicas desenvolvidas	Estratégia / objetivos	Mercado-alvo	Investimento (HQ)	Funcionários envolvidos (pós-graduados)	n. de func. três anos atrás	Tendência -- declinio ou ++ crescimento

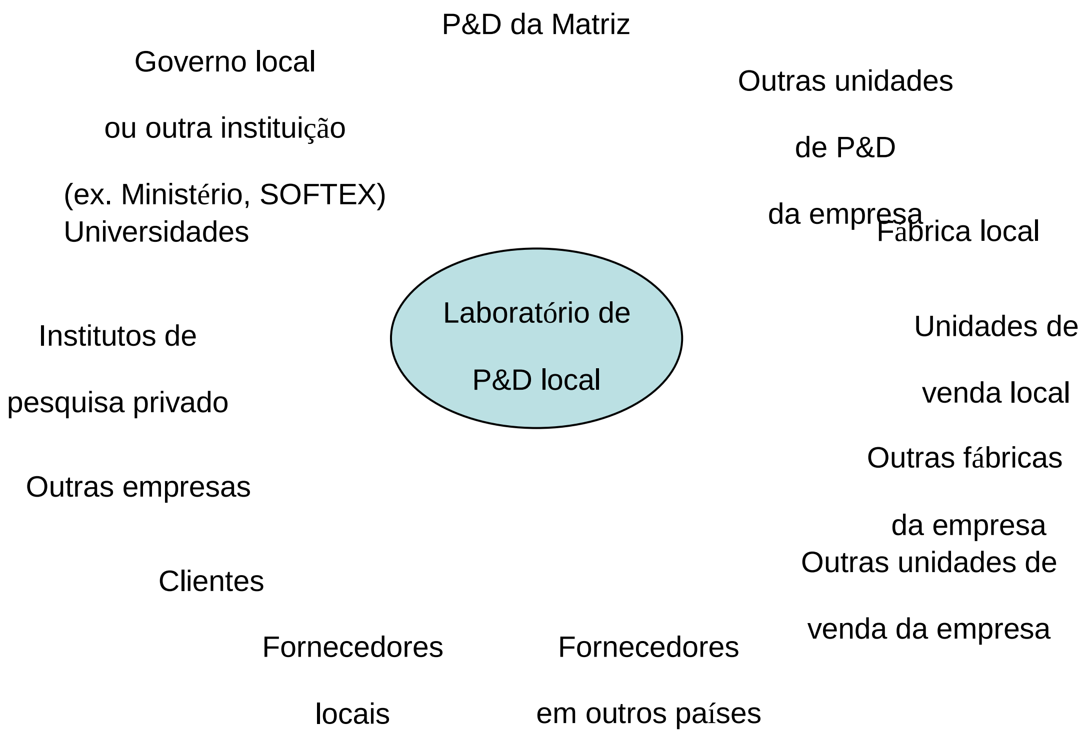
b) Por favor indique o principal objetivo da competência desenvolvida para as organizações envolvidos

c) Para cada uma das competências criadas, acrescente o mercado-alvo, estimativa de investimento e número de funcionários atualmente, nos últimos três anos e tendência futura

d) Quais foram os principais resultados obtidos?

2- REDE DE INOVAÇÃO

A figura abaixo mostra o laboratório local e vários possíveis organizações internas e externas a empresa.
a) Por favor, identique os os principais parceiros através de uma linha



b) Por favor indique a intensidade da interação segundo a seguinte escala:
1=(baixo)ocasional , 2=(médio) menos de uma vez ao mês, 3 (alto) semanalmente
c) Por favor, indique a direção do fluxo de conhecimento tecnológico.
Com uma seta em direcao ao laboratorio marque as principais fontes de conhecimento tecnico
Com uma seta saindo do circulo, maque os principais benefiados do conhecimento gerado no laboratorio

3 -CARACTERÍSTICAS ORGANIZACIONAIS DA UNIDADE DE P&D

a) Qual os principais órgãos de gestão das atividades de P&D dentro da subsidiária? Indique os processos de gestão que vem se desenvolvendo. Quais os principais desafios? O que não funcionou?

b) Quais são os principais mecanismos de coordenação de P&D com a rede multinacional? Indique os processos de gestão vem se desenvolvendo. Quais os principais desafios? O que não funcionou?

c) Como se desenvolveu a relação com os principais parceiros locais? Indique as principais características na seleção do parceiros de P&D. Quais os processos de gestão vem se desenvolvendo? Quais os principais desafios? O que não funcionou?

Parceiro na matriz _______________
Organograma___________________
Direcao_________________________

1. Missão - Explorar vs criar competências - Qual o percentual do pessoal no laboratório trabalhando em:
Criar - Trabalho experimental ou teórico realizado para criar ou adquirir novos conhecimentos que a empresa considera importante para produtos futuros. ____%
Explorar - Trabalho sistêmico, baseado em conhecimento existente dentro da empresa e direcionado a produçao de novos produtos no futuro imediato ou adaptando produtos existentes.____%

2. Interdependência nas tarefas - Por favor, indique uma estimativa do percentual do trabalho da unidade de P&D:
Recebido de outras unidades ______%
Passado para outras unidades ______%

3. Autonomia - Indique o nível de autonomia nos seguintes processos na unidade de P&D:
Decidir a direção geral do esforço de P&D *unidade de P&D* ☐☐☐☐☐ *matriz*
Quais projetos executar *unidade de P&D* ☐☐☐☐☐ *matriz*
Padrões e normas de documentação *unidade de P&D* ☐☐☐☐☐ *matriz*
O orçamento de P&D *unidade de P&D* ☐☐☐☐☐ *matriz*

4. Socialização - No último ano, aproximadamente em quantas ocasiões você ou o seu pessoal
Visitou outras laboratórios da empresa *nunca* ☐☐☐☐☐ *mais de 10 vezes*
Recebeu visitantes de outros laboratórios da empresa *nunca* ☐☐☐☐☐ *mais de 10 vezes*
Pessoal rotação de pessoal de P&D com outras unidades *nunca* ☐☐☐☐☐ *mais de 10 vezes*
Você trabalhou um ou mais anos na matriz de sua corporação? ☐ *Sim*
Você trabalhou um ou mais anos em outras subsidiárias de sua corporação? ☐ *Sim*
Você participou em programas corporativos envolvendo pessoas de outras subsidiárias? ☐ *Sim*
Você tem um mentor ou representante na matriz? ☐ *Sim*

5. Status - Você concorda com as seguintes afirmações?
As competências desenvolvidas na unidade de P&D são tipicamente bem entendidas pela matriz *não concordo* ☐☐☐☐☐ *concordo totalmente*
A competências na unidade de P&D é vista formalmente como um centro de excelência dentro da multinacionais *não concordo* ☐☐☐☐☐ *concordo totalmente*
A credibilidade da direção da subsidiária na matriz é alto *não concordo* ☐☐☐☐☐ *concordo totalmente*

6. Competição interna - Você concorda com as seguintes afirmações?
Projetos são contratados pelas divisões (em oposição a valor fixo pago pelas divisões) *não concordo* ☐☐☐☐☐ *concordo totalmente*
As unidades de negócio possuem escolha por fornecedores de P&D *não concordo* ☐☐☐☐☐ *concordo totalmente*
Para cada dado projeto de P&D existem vários locais que poderiam realizar o trabalho *não concordo* ☐☐☐☐☐ *concordo totalmente*
Trabalho de P&D é por vezes transferido entre localidades como resultado de diferenças de desempenho *não concordo* ☐☐☐☐☐ *concordo totalmente*

7. Inércia organizacional - É comum enfrentar ….
Requisições da matriz para maior justificação a fim de permitir o desenvolvimento de novas competências *não concordo* ☐☐☐☐☐ *concordo totalmente*
Falta de reconhecimento das iniciativas pelas outras subsidiárias *não concordo* ☐☐☐☐☐ *concordo totalmente*
Demora/ Desinteresse pelas iniciativas pelas outras unidades *não concordo* ☐☐☐☐☐ *concordo totalmente*
Rejeição pela gestão corporativa baseada na justificativa de que as iniciativas não endereçam prioridades estratégicas da corporação *não concordo* ☐☐☐☐☐ *concordo totalmente*

8. Por favor, indique em qual direção você as seguintes características da subsidiária tem variado nos últimos três anos:

Missão do Laboratorio *Explorar mais o conhecimento da MNC* □□□□□ *Criar competncias ineditas*

Interdependência nas tarefas *Diminuído significativamente* □□□□□ *Aumentado significativamente*

Autonomia *Diminuído significativamente* □□□□□ *Aumentado significativamente*

*Socializaç*ão *Diminuído significativamente* □□□□□ *Aumentado significativamente*

Status *Diminuído significativamente* □□□□□ *Aumentado significativamente*

Competição interna *Diminuído significativamente* □□□□□ *Aumentado significativamente*

Inércia organizacional *Diminuído significativamente* □□□□□ *Aumentado significativamente*

D - ORIGINAL PROTOCOL USED FOR TECHNOLOGICAL PARTNERS, IN PORTUGUESE

Identificação

Nome:
Cargo:
Departamento:
Tempo de casa:

1 - PROJETOS DE INOVAÇÃO

a) Por favor, cite as principais competências criadas (ex. laboratórios ou equipes de P&D) pelos convênios e período onde elas foram construídas.

Datas	Projeto (ou grupo de projetos)	Estratégia (objetivo)	Mercado-alvo	Investimento (não-Lei)	Funcionários envolvidos (pós-graduados)	n. de func. três anos atrás	Tendência -- declínio ou ++ crescimento

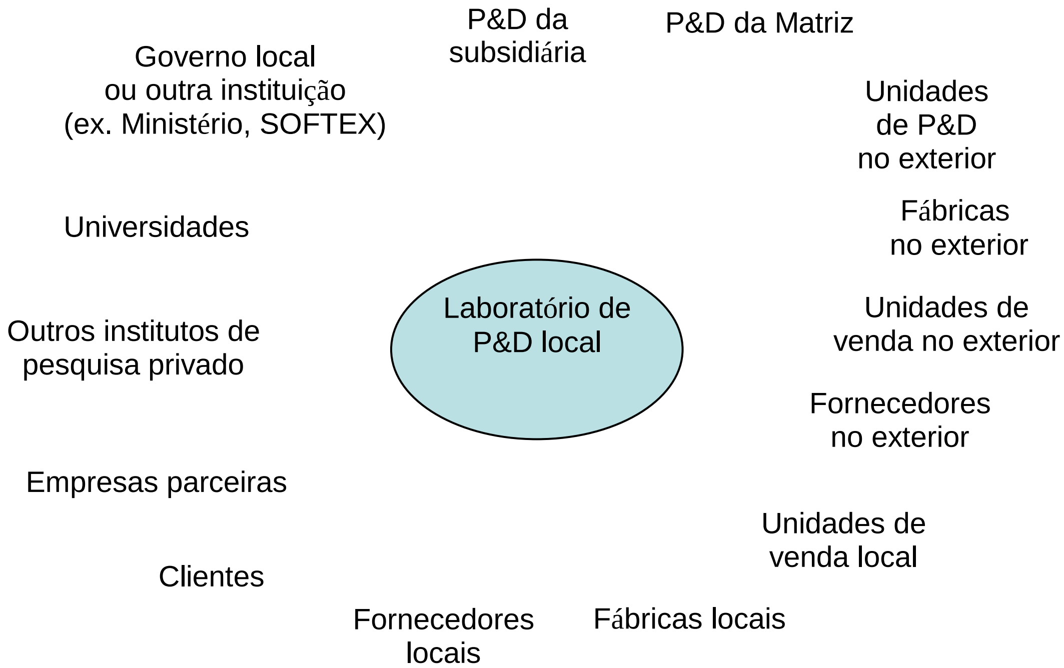
b) Por favor indique o principal objetivo da competência desenvolvida para as organizações envolvidos

c) Para cada dos projetos, acrescente o mercado-alvo, estimativa de investimento e número de funcionários atualmente, nos últimos três anos e tendência futura

d) Quais foram os principais resultados obtidos?

REDE DE INOVAÇÃO

A figura abaixo mostra o laboratório local e vários possíveis organizações internas e externas.
a) Por favor, identifique os principais parceiros através de uma linha.



b) Por favor indique a intensidade da interação segundo a seguinte escala:
1=(baixo)ocasional , 2=(médio) menos de uma vez ao mês, 3 (alto) semanalmente
c) Por favor, indique a direção do fluxo de conhecimento tecnológico.
Com uma seta em direcao ao laboratorio marque as principais fontes de conhecimento tecnico
Com uma seta saindo do circulo, maque os principais benefiados do conhecimento gerado no laboratorio

3 - CARACTERÍSTICAS ORGANIZACIONAIS DA UNIDADE DE P&D

a) Quais os principais órgãos de gestão das atividades de P&D dentro do instituto? Indique os processos de gestão que vem se desenvolvendo. Quais os principais desafios? O que não funcionou?

b) Quais são os principais mecanismos de coordenação de P&D com a rede multinacional? Indique os processos de gestão vem se desenvolvendo. Quais os principais desafios? O que não funcionou?

c) Como se desenvolveu a relação com os principais parceiros locais? Indique as principais características na seleção dos parceiros de P&D. Quais processos de gestão vêm se desenvolvendo? Quais os principais desafios? O que não funcionou?

Parceiro na matriz _______________
Organograma___________________

Direção_________________________

1. Missão - Explorar vs criar competências - Qual o percentual do pessoal no laboratório trabalhando em:

Criar - Trabalho experimental ou teórico realizado para criar ou adquirir novos conhecimentos que a empresa considera importante para produtos futuros. ____%
Explorar - Trabalho sistêmico, baseado em conhecimento existente dentro da empresa e direcionado a produção de novos produtos no futuro imediato ou adaptando produtos existentes.____%

2. Interdependência - Por favor, indique uma estimativa do percentual do trabalho da unidade de P&D:

Recebido da empresa principal ______%
Recebido de outras empresas ______%
Repassado para outras empresas ______%

3. Socialização - No último ano, aproximadamente em quantas ocasiões você ou o seu pessoal técnico

Trabalhou em projetos com institutos similares — *nunca* ☐☐☐☐☐ *mais de 10 vezes*
Trabalhou em projetos com universidades — *nunca* ☐☐☐☐☐ *mais de 10 vezes*
Rotação de pessoal de P&D com a empresa parceira — *nunca* ☐☐☐☐☐ *mais de 10 pessoas*
O responsável pelos projetos já trabalhou um ou mais anos na empresa?
☐ *Sim*
O responsável pelos projetos já trabalhou um ou mais anos em outros institutos?
☐ *Sim*
O responsável pelos projetos participa freqüentemente em atividades de capacitação envolvendo pessoas de outros institutos? ☐ *Sim*
A empresa tem um representante no conselho de administração/ conjunto de associados do instituto? ☐ *Sim*
Você tem um representante no CATI?
☐ *Sim*

4. Status - Você concorda com as seguintes afirmações?

As competências desenvolvidas na unidade de P&D são tipicamente bem entendidas pela empresas no setor	*não concordo*	☐☐☐☐☐	*concordo totalmente*
A competências na unidade de P&D é vista como um centro de referência em nível internacional	*não concordo*	☐☐☐☐☐	*concordo totalmente*
A credibilidade da direção do instituto é alto aos clientes	*não concordo*	☐☐☐☐☐	*concordo totalmente*

5. Governança corporativa – O instituto possui processos definidos para ….

Associação e manutenção de novos membros empresariais	*não concordo*	☐☐☐☐☐	*concordo totalmente*
Envolvimento de menros na tomada de decisão e resolução de conflitos	*não concordo*	☐☐☐☐☐	*concordo totalmente*
processamento e fluxo de informação entre os membros	*não concordo*	☐☐☐☐☐	*concordo totalmente*
Articulação e captura do conhecimento desenvolvido para outros membros	*não concordo*	☐☐☐☐☐	*concordo totalmente*
Processo de negociação de contratos para compartilhamento de propriedade intelectual	*não concordo*	☐☐☐☐☐	*concordo totalmente*
Relatório Anual público com informações sobre a sociedade contendo conjunto adequado de demonstrações financeiras	*não concordo*	☐☐☐☐☐	*concordo totalmente*

6. Competição entre institutos - Você concorda com as seguintes afirmações?

Projetos são contratados por inteiro (em oposição a valor fixo pago por recursos humanos)	*não concordo*	☐☐☐☐☐	*concordo totalmente*
As empresas possuem escolha por fornecedores de P&D	*não concordo*	☐☐☐☐☐	*concordo totalmente*
Para cada dado projeto de P&D existem vários locais	*não concordo*	☐☐☐☐☐	*concordo totalmente*

que poderiam realizar o trabalho

Trabalho de P&D é por vezes transferido entre institutos como resultado de diferenças de desempenho	*não concordo* □□□□□ *concordo totalmente*

7. Por favor, indique em qual direção você as seguintes características da subsidiária tem variado nos últimos três anos:

Missão do Laboratório	*Explorar conhecimento existente* □□□□□ *Criar competências inéditas*
Interdependência nas tarefas	*Diminuído significativamente* □□□□□ *Aumentado significativamente*
Autonomia	*Diminuído significativamente* □□□□□ *Aumentado significativamente*
Socialização	*Diminuído significativamente* □□□□□ *Aumentado significativamente*
Status	*Diminuído significativamente* □□□□□ *Aumentado significativamente*
Competição	*Diminuído significativamente* □□□□□ *Aumentado significativamente*
Governança Corporativa	*Diminuído significativamente* □□□□□ *Aumentado significativamente*

ANNEX 3 – SAMPLE OF PROJECTS CONDUCTED BY SELECTED SUBSIDIARIES BETWEEN 1997-2003

Company	Main Innovation Projects based on total budget
Celestica	Capacity Building - Training, Productive Process Development, Introduction of New Products, Quality System Maintenance, Metrology, PCMM – Professional Certification
Dell	R&D Centre in E-Business, Priority Programmes, Internal System Development-SYNCHRO, Software Factory, R&D Management System, Global R&D Management Tools, Productive Process Development Programme, Software Development Management Centre Programme , Direct Order Management system (DOMS)
Ericsson	R&D centre in Wireless Communication through mobile phones, Applied Product Development - Wired Network, Environment for Operational Courses and Training Development, Frame Relay, Integrated SAP Projects, General Product Development Programme, R&D Programme in CDMA, R&D Programme - Commutation Systems, Data Communication Networks – Development unit
Furukawa	Optical Cable Development, Network Management Integration system, New Families of Optical Cable, System Projects Development, Solution Development for Multiservice Networks , Research on Coaxial Fiber hybrid system development
Hewlett Packard	Diagnostics, Manageability, Software Installation and Configuration, Jet cap, Linux Kernel, OpenBank Architecture, Supportability, TopTools Project
LG	Plasma Monitor 42", LCD Monitor 30", Laboratory Expansion – Public Researcher Antenna, Multimedia Educational Software Applications , R&D Lab Upgrade , Productive Process Environment , Total Quality System, Web Terminal
Lucent	BZ Spack Application, R&D Lab in Data Treatment and Transmission , Information System Development, Phone Centre Evolution BZ5000, Technological Partner Implementation and Operacionalisation Programme, MPEX Project, S-PACK Project, New services ofr Wireless Systems and Internet Access, SDP / GAF
Motorola	Integrated Circuits, Wireless Telecommunication Terminals, K-Java, National Training Programme – University Curricula Development, Product Design Center, Organisational Quality System, SW Centre
Northern Telecom	Mobile Phone Software Development , Lab Implementation , Certification and Homologation Programme , NSM Programme, TDMA-Access Programme, Radio Frequency Engineering Server , CDMA Network Management System
Siemens ltda	Hardware Laboratory, Handset Phone, TNMS, Electronic Digital Switching System, H300, Corporate Quality System, Central Access Card, Transport System
Solectron	Scientific Collaboration agreements, Electronic Boards Manufacturing Process , Computational Models Knowledge Library , Business Intelligence (BI) - CPQD, IT Project Management, Open Software and Bank Automation, Laboratory Expansion – Public Researcher Antenna, TI and Software Development Program, ATM Electronic Equipment ,

ANNEX 4 - LIST OF INTERVIEWS

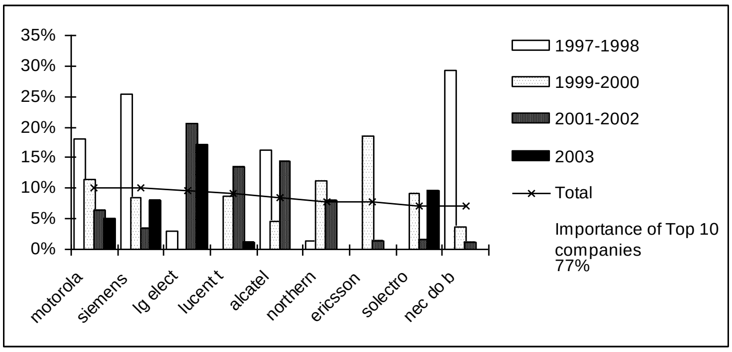
Observation: This Annex will be removed from the public version of this publication given confidentiality requirements.

Subsidiaries	Motorola	Maria Angela	Technological Partners	INFORMAT	Trond
		Rosane		CPqD	Fracisco Siqueira Souza
	Ericsson	Trond		CITS	Guilherme Lorenzi
		Eduardo Oliva			Luiz Claudio Silveira Ramos
	Lucent	Abel Gripp		UNICAMP	Roberto Lotufo
	Furukawa	Hélio Durigan		PUC-PR	Robert Burnett
		Sato		Eldorado	Arthur João Catto
	Dell	Miguel Angelo			Jaylton Moura Ferreira
	HP	Darlei Abreu			Paulo Roberto S. Ivo
		Paulo Sá		CEFET-PR	Douglas Renaux
	Solectron	Franklin da Silva Carvalho			Elane
	Siemens	Ronald Dauscha		Brisa	Paulo F. De V. Toledo
		Mariano		FINATEL	Guilherme Marcondes
	LG	Rogério Silva Martins		FITEC	Lauro Sigaud Ferreira
		David José Ferreira		IPT	Luiz Zipman
	Nortel	Luiz Miranda			
	Celestica	Tosha			

ANNEX 5 – LONGITUDINALANALYSIS OF THE NETWORK AND IDENTIFICATION OF KEY PLAYERS - 1997-2003

Figure 29 –Infra-structure and Equipments

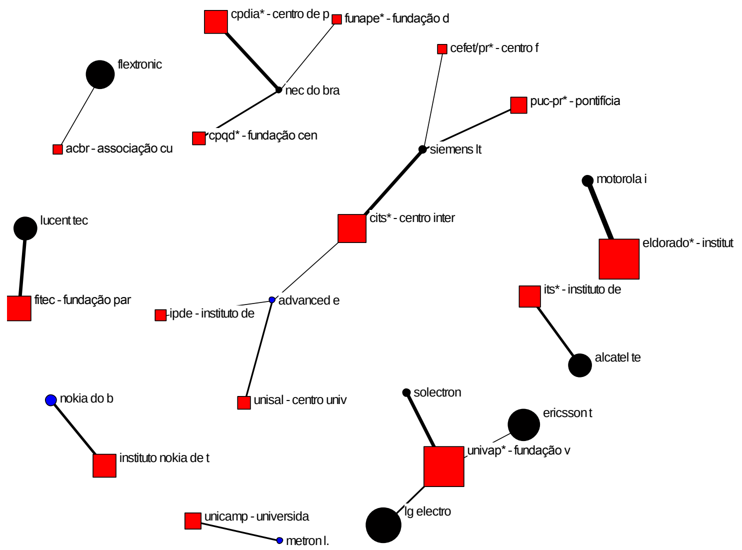
Top 10 Initiatives – Share of Total Investments



Top 10 Organisations – Locus of project implementation

Rank	Executor	Type
1	"univap* - fundação v"	University
2	"eldorado* - institute"	Research Institute
3	"northern t"	Subsidiary
4	"lg electro"	Subsidiary
5	"ericsson t"	Subsidiary
6	"cits* - centro inter"	Research Institute
7	"flextronic"	Subsidiary (2^{nd} tier)
8	"fitec - fundação par"	Research institute
9	"alcatel te"	Subsidiary
10	"cpdia* - centro de p"	Research Institute

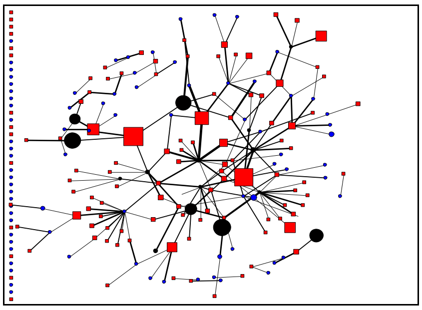
Strong ties between firms and technological partners (universities and research institutes)



Notes:
Red squares correspond to research institutes
Circles correspond to companies (Top 15 MNCs in Black).
Diameter corresponds to the internal investments in technological capabilities.

Basic Network statistics	
Number of firms	142
(with partners)	64
Number of Partners	96
Number of Ties	174
(>R$ 1M)	(18)
Density	407
Sum of Investments	169.7
In partnership (" R$)	103.7
Average tie strength (' R$)	570
Tie/Total (1/’’R$)	1.02
Mean partner investment (' R$)	3456
Maximum tie strength (' R$)	11584

General Network Overview



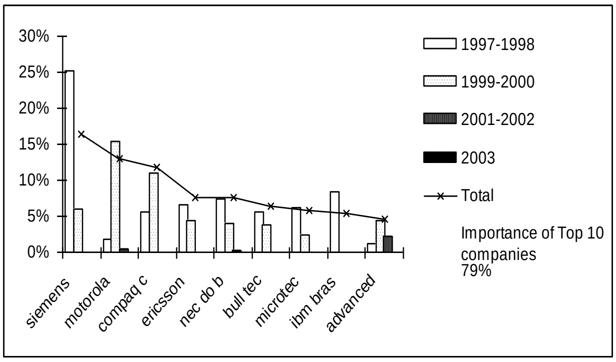
Complexity and firm boundary – 1997-2003

Infrastructure	1997	1998	1999	2000	2001	2002	2003	Average
Investments (% of the Total)	3.5%	4.8%	7.6%	7.6%	9.2%	7.0%	7.2%	6.7%
Investments ("R$)	10.7	16.6	29.6	43.3	22.9	24.4	22.2	24.2
Number of projects	58	54	53	54	45	52	55	53
Average project size ('R$)	184	308	562	801	514	465	402	457
Equiv. Staff/FT *	39	32	27	72	41	9	18	44
Average Cost Man/Hour	25.6	29.5	24.8	27.6	43.2	44.7	30.2	32.5
Internalisation**	15%	19%	54%	53%	37%	25%	33%	38%
Externalisation***	67%	80%	47%	48%	67%	76%	68%	61%
Travel/total	2.1%	0.9%	0.5%	1.4%	0.3%	0.3%	0.3%	0.8%

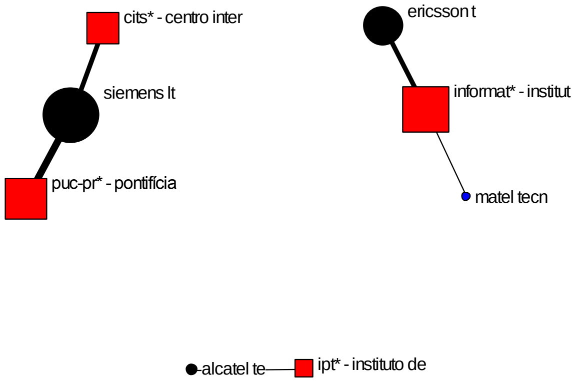
* Estimate number of full-time staff (direct + indirect HR costs)/(Average Cost Man/Hour*2000) ** Projects directly coordinated or executed by the company(Make)/Total *** Investments in Partners, Outsourcing and External training /Total

Figure 30 –Quality systems – Longitudinal analysis – 1997-2003

Top 10 Initiatives - Share of Total Investments



Strong ties between firms and technological partners (universities and research institutes)



Notes:
Red squares correspond to research institutes
Circles correspond to companies (Top 15 MNCs in Black).
Diameter corresponds to the internal investments in technological capabilities.

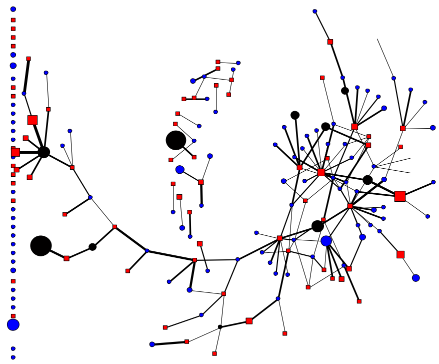
Top 10 Organisations – Locus of project implementation

Rank	Executor		Type
1	"motorola i"		Multinational
2	"compaq com"		Multinational
3	"bull tecno"		Multinational
4	"siemens lt"		Multinational
5	"nec do bra"		Multinational
6	"microtec s"		National
7	"ibm brasil"		Multinational
8	"informat* institut"	-	Research Institute
9	"puc-pr* pontifícia"	-	Private University
10	"ericsson t"		Research Institute
11	"advanced e"		Multinational

Basic Network statistics

Number of firms	170
(with partners)	67
Number of Partners	52
Number of Ties	120
(R$ 1M)	(5)
Density	105
Sum of Investments	118.2
(in partnership (" R$))	27.0
Average tie strength (' R$)	174
Ties/Total (1/’’R$)	0.44
Mean partner investment (' R$)	499
Maximum tie strength (' R$)	3349

General Network Overview



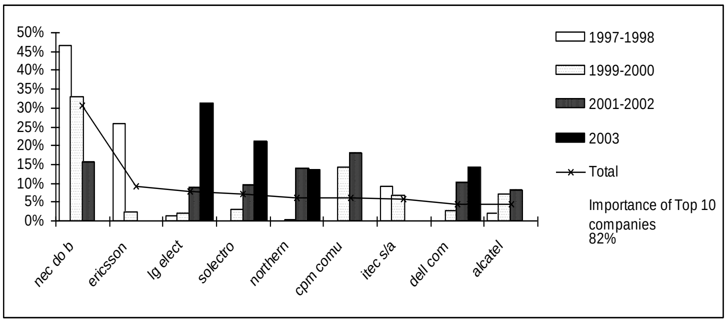
Ratios for complexity and firm boundary– 1997-2003

Quality	1997	1998	1999	2000	2001	2002	2003	Average
Investments (% of the Total)	8.2%	7.1%	6.7%	5.8%	3.9%	n.a.	n.a.	4.8%
Investments ("R$)	24.9	24.5	26.0	33.0	9.8	n.a.	n.a.	17.1
Number of projects	126	108	126	123	42	n.a.	n.a.	77
Average project size ('R$)	199	227	206	269	235	n.a.	n.a.	223
Equiv. Staff/FT *	262	241	284	405	99	n.a.	n.a.	152
Average Cost Man/Hour	28.2	29.6	30.3	28.8	34.8	n.a.	n.a.	29.7
Internalisation**	86%	63%	77%	80%	86%	n.a.	n.a.	77%
Externalisation***	30%	38%	32%	23%	24%	n.a.	n.a.	30%
Travel/total	2.1%	2.7%	1.2%	3.8%	1.9%	n.a.	n.a.	2.4%

Network visualisation and statistics – 1997-2003

Figure 31 – Technological Services – Longitudinal analysis - 1997-2003

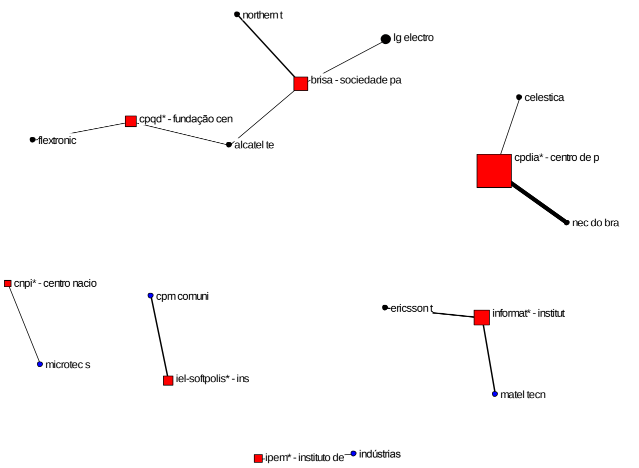
Top 10 Investors - Share of Total Investments



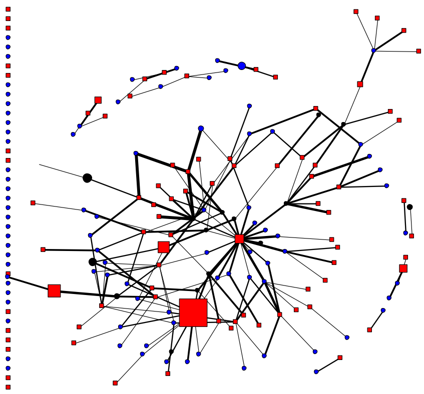
Top 10 Organisations – Locus of project implementation

	Executor	Type
1	"cpdia* - centro de p"	Research institute
2	"informat* - institut"	Research institute
3	"brisa - sociedade pa"	Research institute
4	"cpqd* - fundação cen"	Research institute
5	"solectron "	Subsidiary
6	"iel-softpolis* - ins"	Research institute
7	"itec s/a"	National company
8	"lg electro"	Subsidiary
9	"dell compu"	Subsidiary
10	"ipem* - instituto de"	Research institute
11	"positivo i"	National company

Strong ties between firms and technological partners (universities and research institutes)



Basic Network statistics	
Number of firms	104
(with partners)	76
Number of Partners	71
Number of Ties	170
(R$ 1M)	(12)
Density	258
Sum of Investments (" R$)	84.7
Partnership (" R$)	65.8
Ties/Total (1/’’R$)	2.01
Average tie strength (' R$)	387
Mean partner investment (' R$)	927
Maximum tie strength (' R$)	20957



Notes:
Red squares correspond to research institutes
Circles correspond to companies (Top 15 MNCs in Black).
Diameter corresponds to the internal investments in technological capabilities

Technological Services	1997	1998	1999	2000	2001	2002	2003	Average
Investments (% of the Total)	2.6%	4.1%	4.1%	2.6%	5.0%	2.9%	3.0%	3.4%
Investments ("R$)	7.9	14.1	15.8	15.0	12.4	10.3	9.2	12.1
Number of projects	34	56	71	70	53	52	67	57
Average project size ('R$)	235	251	224	213	235	198	139	211
Equiv. Staff/FT *	20	72	48	84	26	48	73	79
Average Cost Man/Hour	31.0	32.2	35.6	26.5	24.4	34.7	37.0	29.2
Internalisation**	41%	44%	21%	26%	12%	40%	63%	33%
Externalisation***	74%	71%	75%	71%	89%	67%	47%	71%
Travel/total	0.9%	0.9%	0.2%	0.3%	0.5%	0.8%	1.4%	0.7%

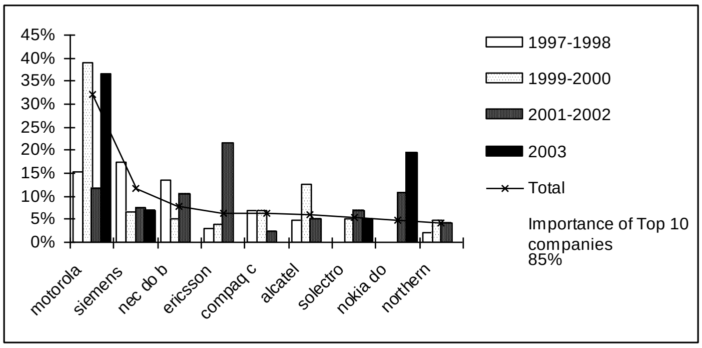
* Estimate number of full-time staff (direct + indirect HR costs)/(Average Cost Man/Hour*2000)

** Projects directly coordinated or executed by the company(Make)/Total

*** Investments in Partners, Outsourcing and External training /Total

Figure 32 – Training in S&T   Longitudinal analysis - 1997-2003

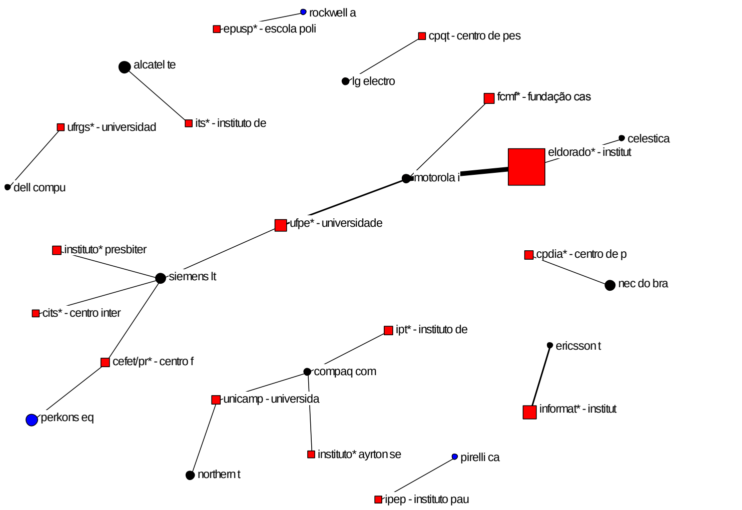
Top 10 Investors - Share of Total Investments



Top 10 Organisations – Locus of project implementation

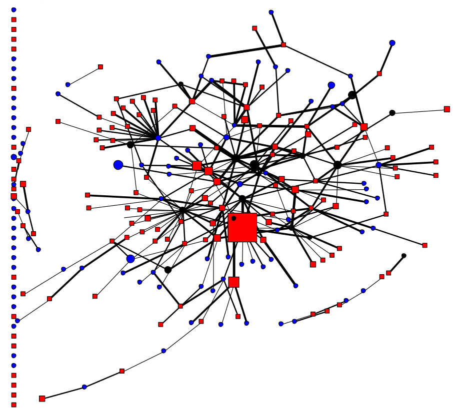
Rank	Executor	Type
1	1- eldorado* - institute	Research Institute
2	"informat* - institut"	Research Institute
3	"ufpe* - universidade"	University
4	"alcatel te"	Subsidiary
5	"nec do bra"	Subsidiary
6	"nokia do b"	Subsidiary
7	"siemens lt"	Subsidiary
8	"positivo i"	National company
9	"lucent tec"	Subsidiary
10	"fcmf* - fundação cas"	University
11	"cefet/pr* - centro f"	University

Strong ties between firms and technological partners (universities and research institutes)



Basic Network statistics

Number of firms	177
(with partners)	87
Number of Partners	117
Number of Ties	259
(> R$ 1M)	(20)
Density	394
Sum of Investments	159.5
Partnership (" R$)	100.4
Tie/Total (1/''R$)	1.62
Average tie strength (' R$)	388
Mean partner investment (' R$)	858
Maximum tie strength (' R$)	28565

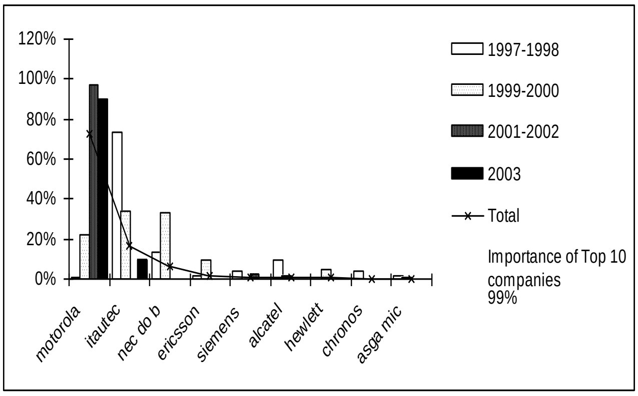


Notes:
Red squares correspond to research institutes
Circles correspond to companies (Top 15 MNCs in Black).
Diameter corresponds to the internal investments in technological capabilities

Training	1997	1998	1999	2000	2001	2002	2003	Average
Investments (% of the Total)	5.3%	5.5%	8.5%	6.0%	6.8%	6.0%	6.2%	6.3%
Investments ("R$)	16.1	19.0	33.1	34.3	17.0	21.1	18.9	22.8
Number of projects	93	124	93	118	68	60	51	87
Average project size ('R$)	174	153	355	291	250	354	369	263
Equiv. Staff/FT *	81	94	122	227	102	104	44	145
Average Cost Man/Hour	37.3	28.1	27.1	20.3	25.2	34.8	26.4	25.5
Internalisation**	55%	47%	31%	42%	31%	56%	34%	41%
Externalisation***	44%	59%	72%	60%	68%	60%	69%	63%
Travel/total	3.4%	2.3%	2.7%	4.0%	2.9%	3.5%	2.8%	3.1%

Figure 33 – Semiconductors Longitudinal analysis - 1997-2003

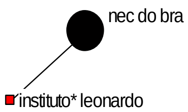
Top 10 Investors - Share of Total Investments

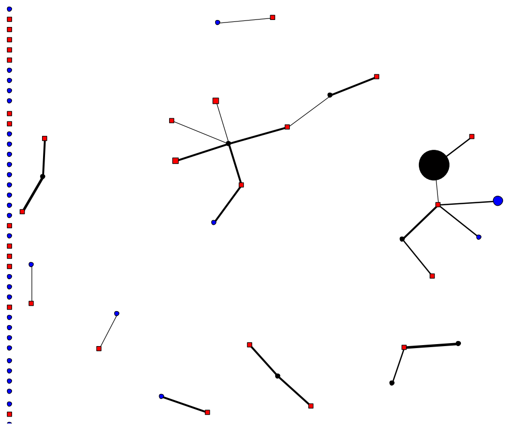


Rank	Executor	Type
1	"motorola i"	Multinational
2	"itautec ph"	Joint-Venture
3	"instituto* leonardo "	Research Institute
4	"fdte* - fundação par"	Research Institute
5	"unicamp - universida"	University
6	"eldorado* - institut"	Research Institute
7	"siemens lt"	Multinational
8	"ipt* - instituto de "	Research Institute
9	"autelcom c"	National
10	"cpqd* - fundação cen"	Research Institute
11	"cefet/pr* - centro f"	University

Basic Network Statistics	
Number of firms	30
(with partners)	15
Number of Partners	18
Number of Ties	24
(>R$ 1M)	(1)
Density	17
Sum of Investments	44.7
Partnership ('' R$)	4
Tie/Total (1/''R$)	0.54
Average tie strength (' R$)	189
Mean partner investment (' R$)	252
Maximum tie strength (' R$)	1427

Strong ties between firms and technological partners (universities and research institutes)



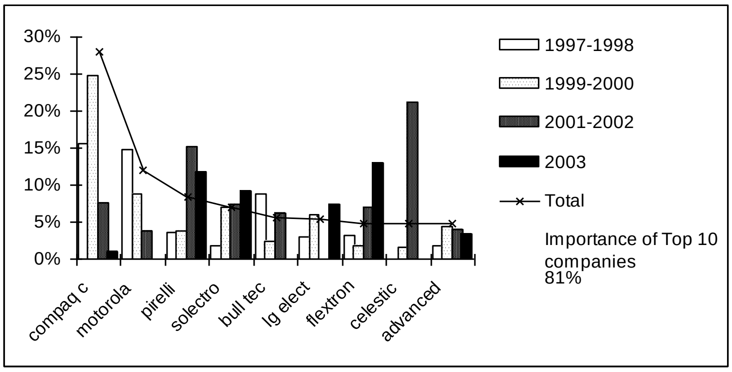


Notes:
Red squares correspond to research institutes
Circles correspond to companies (Top 15 MNCs in Black).
Diameter corresponds to the internal investments in technological capabilities

Microcomponents	1997	1998	1999	2000	2001	2002	2003	Average
Investments (% of the Total)	0.9%	0.8%	0.3%	1.0%	2.5%	3.3%	4.7%	1.8%
Investments ("R$)	2.9	2.8	1.2	5.8	6.2	11.5	14.3	6.4
Number of projects	9	6	5	11	3	5	2	6
Average project size ('R$)	324	478	239	524	1842	2317	6472	1080
Equiv. Staff/FT *	39	38	32	37	70	184	191	30
Average Cost Man/Hour	26.3	32.7	31.8	41.3	40.5	27.3	30.8	36.6
Internalisation**	93%	61%	50%	59%	100%	99%	100%	90%
Externalisation***	14%	30%	18%	42%	0%	1%	5%	12%
Travel/total	7.1%	1.4%	5.1%	3.2%	2.7%	2.3%	1.8%	2.8%

Figure 34 – Production Process   Longitudinal analysis - 1997-2003

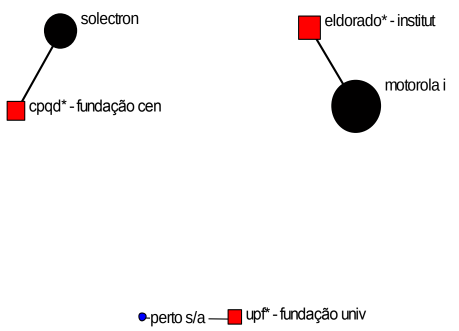
Top 10 Investors - Share of Total Investments

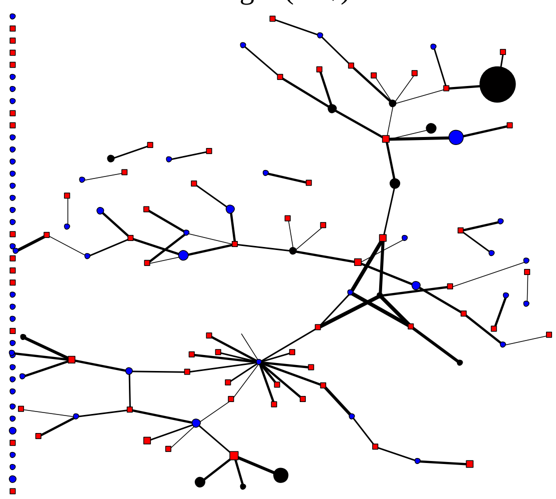


Rank	Executor	Type
1	"compaq com"	Subsidiary
2	"pirelli ca"	Subsidiary
3	"motorola i"	Subsidiary
4	"solectron "	Subsidiary (2^{nd} Tier)
5	"bull tecno"	Subsidiary
6	"lg electro"	Subsidiary
7	"epson paul"	Subsidiary
8	"celestica "	Subsidiary (2^{nd} Tier)
9	"flextronic"	Subsidiary (2^{nd} Tier)
10	"digicon s/"	National Company
11	"jabil circ"	Subsidiary (2^{nd} Tier)

Basic Network statistics	
Number of firms	140
(with partners)	44
Number of Partners	54
Number of Ties	93
Density	53
Sum of Investments	108.9
Partnership (" R$)	13.5
Tie/Total (1/’’R$)	0.49
Average tie strength (' R$)	145
Mean partner investment (' R$)	250
Maximum tie strength (' R$)	1818

Strong ties between firms and technological partners (universities and research institutes)



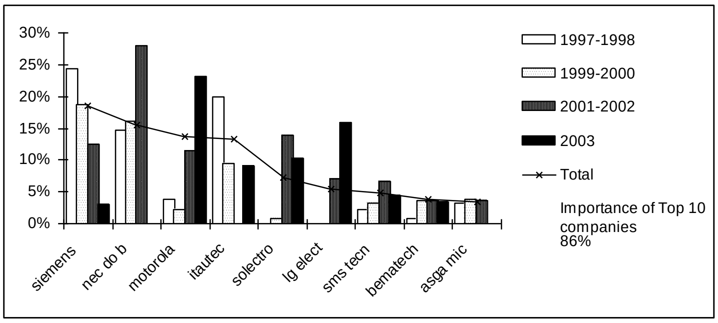


Notes:
Red squares correspond to research institutes
Circles correspond to companies (Top 15 MNCs in Black).
Diameter corresponds to the internal investments in technological capabilities

Production	1997	1998	1999	2000	2001	2002	2003	Average
Investments (% of the Total)	4.5%	4.9%	5.6%	5.8%	3.0%	2.3%	2.3%	4.3%
Investments ("R$)	13.8	16.9	21.9	33.5	7.6	8.0	7.2	15.5
Number of projects	91	73	84	94	25	34	31	61
Average project size ('R$)	152	232	263	355	303	237	233	253
Equiv. Staff/FT *	176	230	253	219	70	81	36	138
Average Cost Man/Hour	27.9	26.8	29.6	31.2	37.3	31.0	53.5	29.8
Internalisation**	96%	81%	92%	90%	96%	88%	72%	89%
Externalisation***	10%	23%	13%	27%	18%	28%	41%	22%
Travel/total	5.0%	2.9%	5.6%	2.8%	0.9%	4.8%	3.2%	3.7%

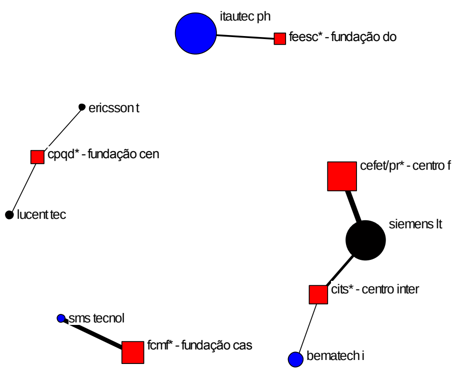
Figure 35 – Development of Products – Hardware - Longitudinal analysis - 1997-2003

Top 10 Investors - Share of Total Investments

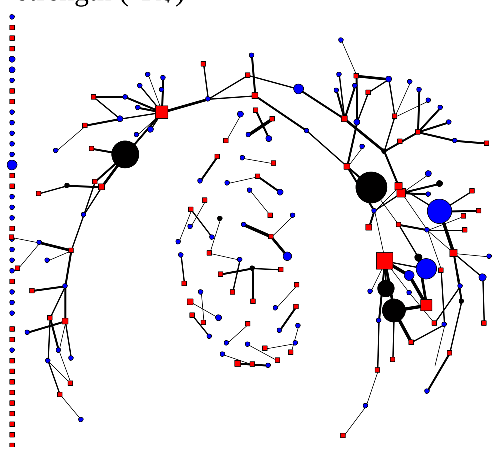


Rank	Executor	Type
1	“nec do bra”	Multinational
2	“Motorola I”	Multinational
3	“itautec ph”	JV
4	“siemens lt”	Multinational
5	“cefet/pr* - centro f”	University
6	“solectron “	Multinational (2nd tier)
7	“lg electro”	Multinational
8	“fcmf* - fundação cas”	Research Institute
9	“cits* - centro inter”	Research Institute
10	“ica teleco”	National Company
11	“asga micro”	National Company

Strong ties between firms and technological partners (universities and research institutes)



Basic Network Statistics	
Number of firms	191
(with partners)	81
Number of Partners	71
Number of Ties	141
(> R$ 1M)	(8)
Density	181
Sum of Investments	203.4
Partnership (" R$)	46.3
Tie/Total (1/’’R$)	0.69
Average tie strength (' R$)	304
Mean partner investment (' R$)	634
Maximum tie strength (' R$)	7300



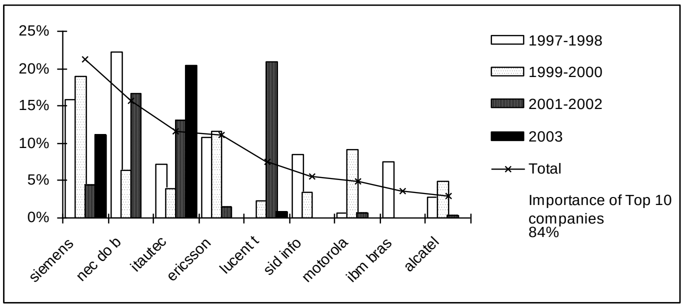
Notes:
Red squares correspond to research institutes
Circles correspond to companies (Top 15 MNCs in Black).
Diameter corresponds to the internal investments in technological capabilities

Hardware	1997	1998	1999	2000	2001	2002	2003	Average
Investments (% of the Total)	7.4%	8.3%	7.5%	7.0%	5.6%	10.3 %	10.6 %	8.1%
Investments ("R$)	22.6	28.9	29.4	40.1	13.9	36.1	32.4	29.1
Number of projects	125	143	168	186	71	155	143	142
Average project size ('R$)	181	202	175	215	195	233	228	205
Equiv. Staff/FT *	269	385	364	321	127	262	174	198
Average Cost Man/Hour	28.4	29.0	26.3	33.3	29.4	38.4	49.0	30.1
Internalisation**	86%	90%	73%	68%	87%	90%	90%	83%
Externalisation***	22%	15%	34%	38%	35%	28%	21%	28%
Travel/total	1.9%	2.9%	1.3%	1.9%	0.5%	5.0%	4.5%	2.8%

Figure 36 – Development of Middleware (HW+SW)   Longitudinal analysis - 1997-2003

Rank	Executor	Type
1	"siemens lt"	Multinational
2	"nec do bra"	Multinational
3	"informat* - institut"	Research Institute
4	"fitec - fundação par"	Research Institute
5	"fmm* - fundação de e"	Research Institute
6	"ipt* - instituto de "	Research Institute
7	"ericsson t"	Multinational
8	"alcatel te"	Multinational
9	"ibm brasil"	Multinational
10	"motorola i"	Multinational
11	"itautec ph"	JV

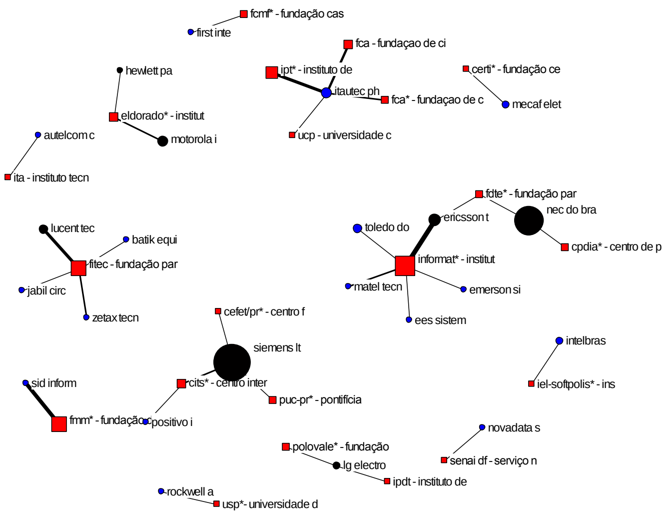
Top 10 Investors - Share of Total Investments



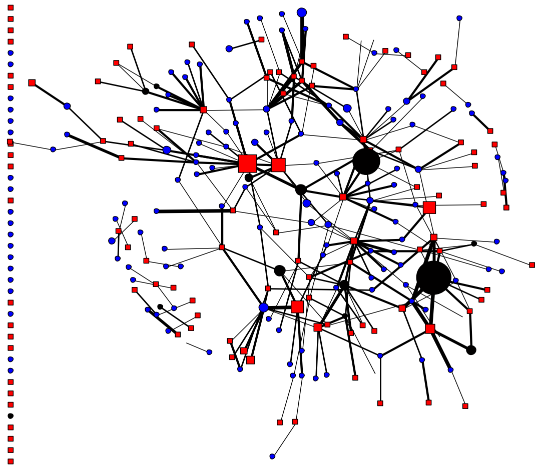
Basic Network Statistics

Number of firms	234
(with partners)	127
Number of Partners	92
Number of Ties	266
(> 1M R$)	(31)
Density	834
Sum of Investments	621.7
Partnership (" R$)	212.4
Ties/Total (1/’’R$)	0.43
Average tie strength (' R$)	799
Mean partner investment (' R$)	2309
Maximum tie strength (' R$)	28188

Strong ties between firms and technological partners (universities and research institutes)



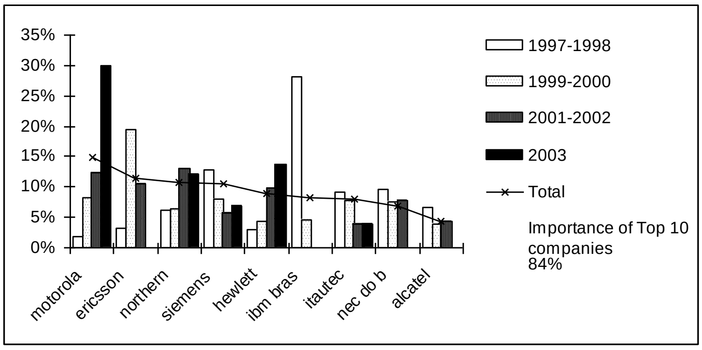
Notes:
Red squares correspond to research institutes
Circles correspond to companies (Top 15 MNCs in Black).
Diameter corresponds to the internal investments in technological capabilities



Middleware (HW+SW)	1997	1998	1999	2000	2001	2002	2003	Average
Investments (% of the Total)	35.3%	31.8%	23.5%	22.7%	21.3%	21.8%	17.3%	24.7%
Investments ("R$)	107.6	110.4	91.4	130.1	53.1	76.1	53.0	88.8
Number of projects	275	315	301	431	148	306	278	294
Average project size ('R$)	391	350	303	302	358	249	190	303
Equiv. Staff/FT *	849	971	762	1040	415	464	384	747
Average Cost Man/Hour	32.3	34.3	34.4	40.1	34.1	39.5	44.5	36.4
Internalisation**	70%	81%	73%	74%	60%	88%	79%	75%
Externalisation***	30%	35%	35%	29%	49%	48%	37%	36%
Travel/total	3.1%	1.9%	2.5%	2.9%	0.8%	0.8%	1.0%	2.1%

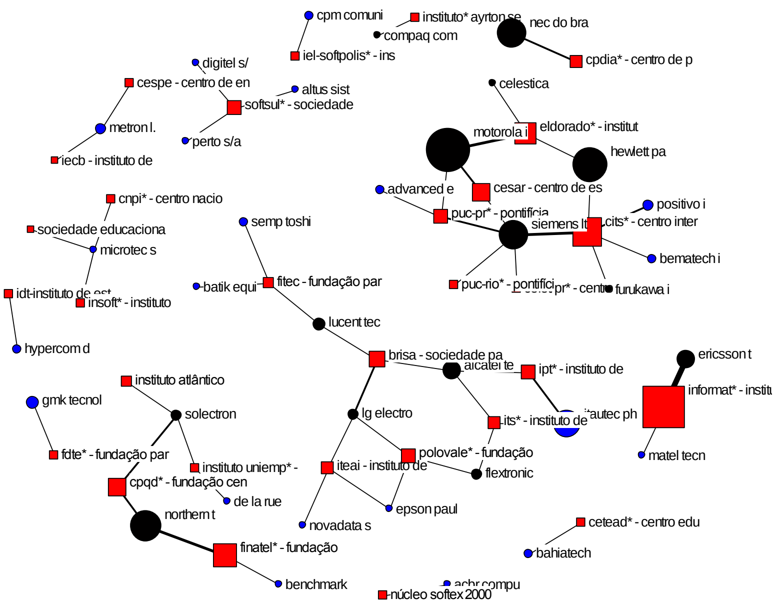
Figure 37 – Development of Software Longitudinal analysis - 1997-2003

Top 10 Investors - Share of Total Investments



Rank	Executor	Type
	"informat* - institut"	Research Institute
	"motorola i"	Multinational
	"ibm brasil"	Multinational
	"hewlett pa"	Multinational
	"northern t"	Multinational
	"cits* - centro inter"	Research Institute
	"nec do bra"	Multinational
	"siemens lt"	Multinational
	"itautec ph"	JV
	"finatel* - fundação "	Research Institute
	"eldorado* - institut"	Research Institute

Strong ties between firms and technological partners (universities and research institutes)



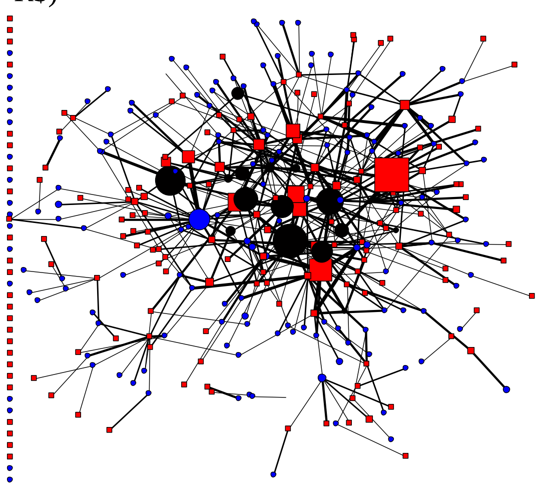
Notes:

Red squares correspond to research institutes

Circles correspond to companies (Top 15 MNCs in Black).

Diameter corresponds to the internal investments in technological capabilities

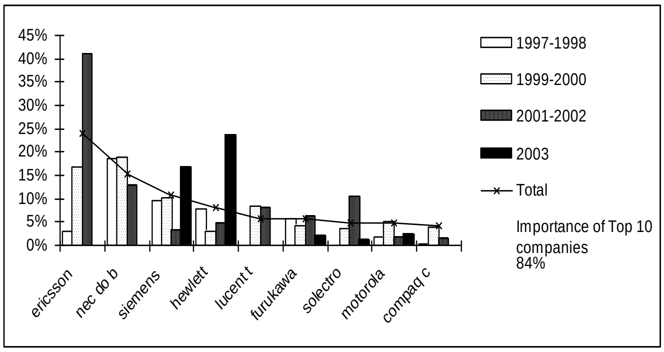
Basic Network Statistics	
Number of firms	271
(with partners)	157
Number of Partners	140
Number of Ties	464
(>1M R$)	(56)
Density	1512
Sum of Investments	838.3
Partnership (" R$)	385.0
Ties/Total (1/ ‘’R$)	0.55
Average tie strength (' R$)	830
Mean partner investment (' R$)	2750
Maximum tie strength (' R$)	58622



Software	1997	1998	1999	2000	2001	2002	2003	Average
Investments (% of the Total)	27.7 %	27.2 %	30.7 %	29.9 %	37.6 %	39.6 %	44.6 %	33.3%
Investments ("R$)	84.3	94.5	119.5	171.3	93.8	138.4	136.5	119.8
Number of projects	284	351	376	436	226	426	327	346
Average project size ('R$)	297	269	318	393	416	325	417	346
Equiv. Staff/FT *	758	638	624	1005	510	808	586	652
Average Cost Man/Hour	31.2	31.9	36.9	38.7	36.8	39.5	49.8	36.8
Internalisation**	70%	71%	61%	64%	56%	55%	46%	60%
Externalisation***	43%	52%	52%	41%	57%	56%	53%	50%
Travel/total	3.5%	3.6%	2.0%	3.1%	0.8%	1.6%	1.9%	2.4%

Figure 38 – Research - Longitudinal analysis - 1997-2003

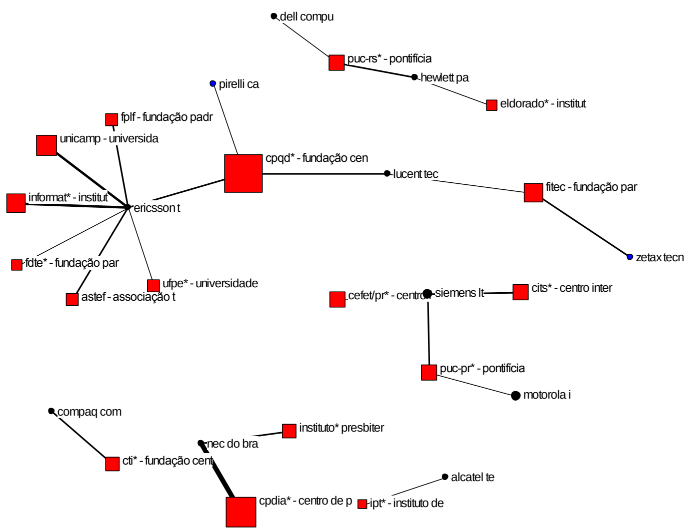
Top 10 Investors - Share of Total Investments

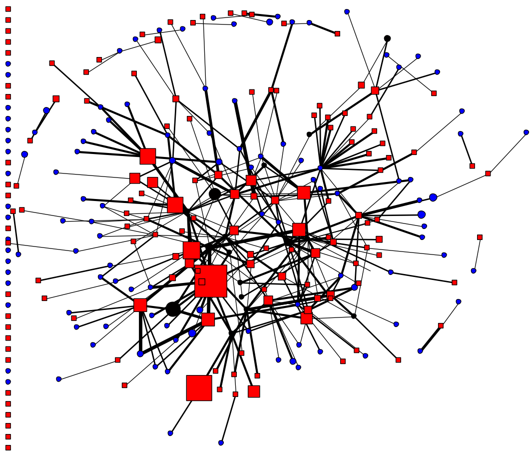


Executor	Type
"cpqd* - fundação cen"	Institute
"cpdia* - centro de p"	Institute
"unicamp - universida"	University
"fitec - fundação par"	Institute
"informat* - institut"	Institute
"furukawa i"	Multinational
"puc-pr* - pontifícia"	University
"puc-rs* - pontifícia"	University
"cits* - centro inter"	Institute
"cefet/pr* - centro f"	University

Basic Network	
Number of firms	195
(with partners)	111
Number of Partners	121
Number of Ties	315
(>1M R$)	(23)
Density	381
Sum of Investments	121
Ties/Total (1/’’R$)	2.6
Partnership (" R$)	97.2
Average tie strength (' R$)	309
Mean partner investment (' R$)	803
Maximum tie strength (' R$)	9229

Strong ties between firms and technological partners (universities and research institutes)





Notes:

Red squares correspond to research institutes

Circles correspond to companies (Top 15 MNCs in Black).

Diameter corresponds to the internal investments in technological capabilities

Research	1997	1998	1999	2000	2001	2002	2003	Average
Investments (% of the Total)	3.9%	3.5%	3.9%	6.8%	4.6%	5.7%	3.5%	4.8%
Investments ("R$)	11.9	12.2	15.3	39.3	11.5	20.1	10.8	17.3
Number of projects	90	105	113	161	82	123	86	109
Average project size ('R$)	132	116	136	244	141	163	127	159
Equiv. Staff/FT *	121	64	65	91	63	82	48	132
Average Cost Man/Hour	28.3	28.2	28.6	25.6	23.4	20.9	32.4	24.6
Internalisation**	24%	30%	28%	12%	28%	16%	38%	22%
Externalisation***	50%	68%	70%	85%	70%	82%	70%	74%
Travel/total	2.0%	1.3%	1.0%	0.8%	1.2%	0.3%	0.5%	0.9%

* Estimate number of full-time staff (direct + indirect HR costs)/(Average Cost Man/Hour*2000)

** Projects directly coordinated or executed by the company(Make)/Total

*** Investments in Partners, Outsourcing and External training /Total

ANNEX 6 – LONGITUDIONAL ANALYSIS OF THE KEY PLAYERS IN THE SECTOR

Observation: This Annex will be removed from the public version of this publication given confidentiality requirements.

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ANNEX 7 – HISTORICAL EXCHANGE RATE