Handbook of Innovation Systems and Developing Countries

Building Domestic Capabilities in a Global Setting

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6 Regional innovation systems in developing countries: integrating micro and meso-level capabilities

Ramón Padilla-Pérez, Jan Vang and Cristina Chaminade

6.1 Introduction

In recent years, there has been increasing interest in the rapid growth of certain regions and industries in developing countries. The new global landscape – characterized by rapid technological development and change, economic globalization, new business strategies and deregulation – has opened new windows of opportunity for upgrading and growth in developing countries (Archibugi and Pietrobelli, 2003). A 'handful' of regions in the developing world have already managed to utilize the opportunities that the new global landscape provides to accumulate technological capabilities and occasionally even become specialized hubs in global knowledge networks (Chaminade and Vang, 2008a; Asheim et al, 2007b). While some countries and regions show clear signs of being on the right track, others – especially in Africa and parts of Latin America – are falling behind in terms of upgrading, growth, unemployment and poverty (Kaplinsky, 2005).

There appear to be no 'best practice' lessons that can be learnt from the successful regions as they have followed highly diverse industrialization, development and upgrading paths. The countries and regions also have different sizes (that is, home markets), human, social, financial and physical endowments and follow different, partly path-dependent, policy intervention strategies.[1] The analysis of existing experiences is also limited by the absence of systematic comparative analysis of different regions and industries across the globe. Hitherto, the existing literature has tried to explain differences in the performance of the various regions focusing on the strategy of particular firms, the vertical and horizontal links in the clusters, the human capital endowment, the orientation to export markets and the role of the state.

Several studies in both developed and developing countries link successful upgrading to the exploitation of agglomeration economies (Scott and Garofoli, 2007). In this context, scholars, consultants and policy makers have increasingly acknowledged the importance of analysing and *constructing* regional innovation systems (RIS) as a means for facilitating catching-up processes in firms in developing countries (Asheim et al., 2007b). This has spurred an invaluable stream of literature re-theorizing, re-conceptualizing and adapting the ideas behind RIS and related concepts (that is, clusters) to the specificities and contingencies of developing countries (Lundvall et al., 2006; Chaminade and Vang, 2006; Pietrobelli and Rabellotti, 2005 and 2006; Yeung, 2006; Vang and Asheim, 2006; Guiliani et al., 2005; Schmitz, 2006). Yet, while this stream of research has provided valuable insights into the role of RISs in supporting upgrading in firms in developing countries, there are still significant theoretical and methodological gaps. Theoretically, the existing literature continues to be rather generic, ignoring the specificities of the firms located in the RIS in developing countries (their strategy and role in the value chain) or the specific stage in the evolution of the RIS (Chen and Vang, 2008; Chaminade and Vang, 2008a). Methodologically, it is also suggested that there is a need to move from individual cases to the systematic comparison of regions, and to develop a systematic and rigorous method to study the dynamics of regional innovation systems in developing countries in a comparative perspective (Chaminade and Vang, 2006).

This chapter aims to contribute to this stream of research by investigating the need to adapt RISs to the specificities of developing countries and proposes a method to systematically analyse and compare the performance of RIS in supporting upgrading of firms in developing countries. In this respect, the chapter contributes to the existing literature by contextualizing the discussion of the importance of different interactions within the RIS to the type of firm (that is its technological capabilities and its position in the global value chain). Additionally, the chapter proposes a new methodology to conduct comparative analysis on the role of RIS supporting capability-building among (indigenous) firms.

In order to do this, we will focus on the analysis and comparison of two regions in Mexico with a strong presence of firms in the electronics industry (Jalisco and Baja California). By applying the framework developed in the first part of the chapter, we will analyse the differences in the role of two RISs supporting the development of technological capabilities by the firms located in the region. The chapter draws on original data collected on-site in two Mexican regions.

The reminder of the chapter is structured as follows. First, the theoretical section is presented. This section synthesizes and critically revises the fragmented bits of the literature on RISs and upgrading of firms in developing countries with the aim of deriving specific testable hypotheses. This is followed by a methodological section that introduces how qualitative

BOX 6.1 REGIONAL INNOVATION SYSTEMS IN DEVELOPING COUNTRIES: MAIN TERMS USED

Regional innovation system: 'a constellation of industrial clusters surrounded by innovation supporting organizations' (Asheim and Coenen, 2005).

Firm upgrading: the capacity of a firm to innovate or increase the value-added of its products or processes (Humphrey and Schmitz, 2002).

Firm-level production capabilities: the capabilities needed to produce goods using existing technologies.

Firm-level innovative capabilities: in contrast to the production capabilities, innovative capabilities are those needed to generate and manage technical change. They are considered advanced capabilities, while production capabilities are considered basic capabilities.

Regional technological capabilities: knowledge and skills embedded in individuals, organizations and institutions located in a geographically-bounded area and conducive to innovative activity (Padilla-Pérez, 2008b). It is important to stress that regional technological capabilities are not simply the sum of firm-level capabilities but the result of their interaction at a regional level.

and quantitative data sources are integrated and presents the specific measures used for testing the hypotheses. We then apply the proposed method to the comparison of two RISs in Mexico – Jalisco and Baja California – where we test the hypotheses. The chapter is concluded by discussing its contribution as well as further (methodological) challenges and implications for policy makers.

6.2 Regional innovation systems in the literature

6.2.1 The concept

This chapter foundation is constituted by the regional innovation systems approach (henceforth RIS approach). An RIS is defined as a 'constellation of industrial clusters surrounded by innovation supporting organizations' (Asheim and Coenen, 2005). Industrial clusters refer to the geographic concentration of firms in the same or related industries (Porter, 1998; Pietrobelli and Rabellotti, 2004; for a critique, see Martin and Sunley, 2003). The concept of RISs was developed on the basis of and inspired by successful regions and clusters such as Silicon Valley (Cohen and Fields, 1998; Saxenian, 1994), Baden Württemberg (Staber, 1996) and the Third Italy (Beccatini, 1990; Piore and Sabel, 1984). As such, most of the literature on regional innovation systems reflects the traits and characteristics of the developed world. It has even been suggested that the so-called Holy Trinity or Triad (Europe, Japan and the United States) does not reflect the developed world as such, but 'outlier' regions (Intarakumnerd and Vang, 2006). Across the different interpretations, RIS approaches stress the systemic dimensions or propensities of the innovation process, being the dynamic interaction between the different components of the system, that is individuals, organizations and institutions and their interactions (that is, viewing innovation as an interactive process, not a linear one).

Conceptually RISs are conceived as *ex post* rationalizations of the aforementioned success cases, that is, what the literature considers to be a well-functioning system is mainly a generalization of the successful cases of Silicon Valley, Baden Württemberg or the Third Italy. RISs in developing countries can be understood as *ex ante* constructions of RISs (Intarakumnerd and Vang, 2006; Lundvall et al., 2006), where in most cases we can only find some of the elements of an emergent RIS. RISs in developed and developing countries face fundamentally different theoretical challenges as they are embedded in different institutional frameworks. RISs in developing countries have typically weak indigenous formal institutions and strong international governance bodies and temporal specificities (catching up as opposed to being first movers) and – often – rely on capital and knowledge originating not just outside the sub-national region's borders but outside the country (Amin, 2004; Loebis and Schmitz, 2005; Pietrobelli and Rabellotti, 2006; Schmitz, 2006). The lack of local knowledge resources in RISs in developing countries forces the indigenous firms to rely much more on TNCs as providers of knowledge and capital (Pietrobelli and Rabellotti, 2006; Schmitz, 2006; Vang and Asheim, 2006).

In this context, a critical question is under which conditions RISs in developing countries can support upgrading and the acquisition of technological capabilities by indigenous firms. In this sense, it is useful to distinguish between upgrading in firms and upgrading of the whole system. Firm upgrading is defined as the capacity of a firm to innovate and/or increase the value-added of its products and processes (Humphrey and Schmitz, 2002; Chaminade and Vang, 2008b). Similar to firms, a regional system possesses technological capabilities, understood as 'knowledge and skills embedded in individuals, organizations and institutions located in a geographically-bounded area and conducive to innovative activity' (Padilla-Pérez, 2008b, p. 69). Regional 'systemic' innovation capabilities are not simply the sum of individual firm-level technological capabilities developed in isolation (Lall, 1992). A region embeds many systemic elements external to the firm, which influence its technological competence and growth (Cooke et al., 1997; Howells, 1999; Evangelista et al., 2002; Iammarino, 2005). Meso-level capabilities thus cannot only be conceptualized as the sum of the technological capabilities of the innovation-oriented organizations in the region; their interactions are considered crucial (von Tunzelmann, 2006). Nevertheless, the development of regional capabilities, which share most of the features of firm-level capabilities in that regional learning is a long, uncertain and costly process, displays high path-dependence and cumulativeness.

Well-functioning RISs are commonly characterized by the high level of technological capabilities of the organizations in the system, the large scale and scope of interactions among sub-systems, as well as the intensity, density and breadth of the outward flows with the rest of the world. That is, RISs should not be reduced to interactions within the local actors, but should also embrace knowledge flows with other organizations located outside the region (Giuliani et al., 2005; Vang and Chaminade, 2006; Chaminade and Vang, 2006). The scope of the interactions is strongly influenced by the institutional framework. The institutions (the rules, norms and values) are seen as the regulating devices ordering, in a non-deterministic way, the behaviour of the actors and their interaction in the RIS.

Finally, the system of innovation can be shaped by science, technology and innovation policy – not to mention other policy topics such as industrial policies and sound macroeconomic policies. Yet, as emphasized by much of the development literature (that is with focus on the (post) Washington consensus) and underscored by Isaksen (2003), the functioning of the RIS is also influenced by policies designed and implemented outside the boundaries of the region, for example through national science and technology policy and central decisions about the extent and level of regional administrative devolution. Generally speaking, RIS policy is argued to improve the performance of the regional innovation system by supporting the creation, acquisition and retention of technological capabilities and the diffusion of relevant knowledge among the actors embedded in the system. But the objectives and the instruments that might be used for each RIS as well as the degree of intervention of the government in the regional system of innovation vary significantly across regions (Asheim and Isaksen, 2002; Vang and Chaminade, 2006).

6.2.2 Adapting RISs to developing countries

As discussed earlier, most RISs in developing countries do not show the high degree of integration and interaction that characterizes RISs in developed countries. The technological level of the different organizations in the system is frequently low, their interactions are weak and they are, in general, more dependent on external flows of knowledge and technology. In this context, most of the assumptions in the literature need to be adapted to the specificities of developing countries and regions (Chaminade and Vang, 2006; Vang and Chaminade, 2008; Vang et al., forthcoming). We will now turn to the most central dimension of RISs, synthesizing the general RIS literature with special attention to the new attempts at adapting RISs to the specificities of developing countries. By doing so, we will develop a set of hypotheses on the role of RISs in supporting firm upgrading in developing countries. For each component of the RIS, we arrive at one hypothesis derived from the existing literature. In section 6.3, the hypotheses will be tested in two regions in Mexico.

Integration and interaction in innovation systems in developing countries Much research within economic growth and economic development has focused on either the supply or the demand side of the development process. In contrast, the RIS approach puts the emphasis on the *systemic* dimension of the innovation process (Lundvall, 1992; Asheim and Gertler, 2004); that is, the dynamic interaction between the different components in the system and the impact of the system's strong or weak components on the dynamic efficiency of the system as a whole. Innovation systems (IS) research (Freeman, 1987; Lundvall, 1992; Nelson, 1993; Edquist, 1997) emerged as a response to the more linear model of innovation dominant mainly in the US until the 1980s. IS research emphasized that innovation could occur outside the 'labs or domain of science and technology'; innovation systems research has especially stressed the interface between users and producers. Lundvall's seminal text on user–producer interaction in the Danish dairy sector is one of the cornerstones in this literature (Lundvall, 1988).

Scholars within the RIS approach have mainly focused on the localized nature of these interactions, emphasizing the tacit component of knowledge. Knowledge is considered to be embedded in specific institutional settings where local recipients share values, visions, organizational forms and so on that allow them to 'decode' the tacit knowledge available to them and thus increase their ability to tap into tacit knowledge (Gertler, 2004; Asheim et al., 2007a). Thus, most RIS researchers argue that interactive learning is facilitated by physical proximity.[2]

Well-functioning RISs, such as the ones found in the developed world with intensive interactions between the different organizations in the system, are far from common in the developing context. In this sense, RISs in developing countries should be understood as 'immature RISs' or emerging RISs where some of the building blocks are in place and the interactions among the elements of the RIS are still in formation and thus appear fragmented (Chaminade and Vang, 2008a; Galli and Teubal, 1997), thus failing to perform on the same level as mature RISs. However, a high degree of integration and interaction is central to the development of advanced firm-level technological capabilities in developing countries.

H1: There is a direct relationship between firms' advanced capabilities and well-functioning RISs (that is, we expect firms in RISs displaying a high degree of integration and interaction to have more advanced capabilities).

TNCs and the RIS Innovation studies have tended to emphasize endogenous growth dynamics, focusing mainly on indigenous capacity-building. However, several of the clusters that served as inspiration for RISs' theoretical development are restructuring and reconstructing the boundaries between the local and the global. Well-functioning RISs such as Silicon Valley are increasingly being knitted with other global hubs such as Hsinchu Science Park in Taiwan and Bangalore in India (Saxenian, 2006). The so-called global–local linkages have been elevated to the forefront of RIS studies, and this is considered especially critical for developing countries. As argued before, developing countries often lack local resources needed for acquiring advanced technological capabilities. They are much more dependent on external sources of knowledge.

It is argued that the ability of developing countries to tap into, absorb and leverage global flows of traded and untraded knowledge is one of the most important determinants of the performance of their upgrading. Yet not all global interactions lead to the expected positive results. FDIs, for example, are not a priori assumed to lead to positive direct or indirect spillovers as their impact will depend, among other issues, on the subsidiaries' local embeddedness, the R&D mandate, the decision-making structure of the TNC or, more generally, industry, institutional, temporal and firm-specific characteristics (Pack and Saggi, 1997; Padilla-Pérez, 2008a; Radosevic, 1999; UNCTAD, 2005). Based on this, the following hypothesis can be deduced:

H2: The interaction between foreign subsidiaries and locally-owned firms is important to develop advanced technological capabilities in RISs in developing countries, yet it is not an automatic process.

Users in innovation systems in developing countries Innovation systems research has long emphasized the importance of user–producer interaction for upgrading and innovation (Castellacci, 2006; Fagerberg, 2004; Lundvall, 1988; Jeppesen and Molin, 2003; Lüthje et al., 2005; Thomke and Von Hippel, 2002). The emphasis on the user–producer interaction stems from the fact that innovations often occur in response to specific problems that emerge from the interaction between the user and the producer. This represents the foundation for breaking away from the linear innovation model, and supply or demand models in general. Recently, the literature focus has shifted towards lead users, defined as users that perceive needs well ahead of the mass market and that, often, have developed their own innovative adaptive solutions (Franke and von Hippel, 2003; Franke and Shah, 2003; Jeppesen and Frederiksen, 2006).

The interaction with users might support incremental innovations, while interaction with lead users might be more important for more radical innovations and thus more valuable for the innovative firm. Nevertheless most studies confirm that lead users are also mostly involved in creating incremental innovations (Jeppesen and Frederiksen, 2006). The user–producer model relies on the assumption that the user and the producer have 'equal' incentives for sharing the knowledge required for successful collaboration and that both have sufficient in-house human capital to absorb and use the exchanged information and knowledge or at least that the interaction constitutes a win–win situation. This approach has spurred an interesting and also critical debate concerning many different issues – for example on the relevancy of lead users' preferences versus the mass market's preferences as well as studies of the importance of users in an evolutionary perspective (Chaminade and Vang, 2008a). Exports can be seen as a – rough – proxy for interaction with users at distant locations. Foreign buyers who are a potential source of new technologies, and exposure to international markets may help exporters to keep informed of new products and processes (ECLAC, 2004; Machinea and Vera, 2006; Padilla-Pérez and Martínez-Piva, 2007). Thus:

> *H3:* Export to the world market stimulates upgrading in firms located in RISs in developing countries (as more advanced users are located overseas).

Universities and innovation systems in developing countries Universities have always been considered a crucial element in innovation systems. These organizations play a major role in originating and promoting the diffusion of knowledge and technologies that contribute to industrial innovations (Mansfield and Lee, 1996, p. 1047). In particular, research universities are important as sources of fundamental knowledge and industry-relevant technology in modern knowledge-based economies (Mowery and Sampat, 2004).

In the early phases of the emergence of the RISs, universities might play a crucial role as providers of qualified human capital. However, as firms acquire more advanced technological capabilities and move up to more innovation-intensive activities, they might require from the universities more industry-specific research, thus pointing to the importance of a more developmental role. Overall, the situation in developing countries is one of a fragmented system of innovation, where in most cases it is possible to identify a handful of firms with advanced technological capabilities and for which universities play a crucially important role in providing them with industry-specific knowledge. On the other hand, most firms in RISs in developing countries have basic or intermediate technological capabilities and require from the universities a much more basic role of provision of qualified human capital (Vang et al., forthcoming). Thus:

> *H4:* Universities in developing countries are expected to play mainly a role of provision of highly qualified human capital.

State intervention in innovation systems in developing countries Contrary to other system approaches such as Luhmann's (1995), which implies self-regulating and closed systems, innovation systems research postulates that systems cannot be seen in isolation from their institutional framework, thus the idea of self-organizing systems is considered as rather meaningless.[3] Traditionally, innovation systems research has highlighted the role of policies targeting systemic problems (Chaminade and Edquist, 2006). While the NSI approach emphasizes the role of the national state (that is, central government bodies) and devotes much attention to defending and rethinking the role of the national state in the context of increased globalization (Archibugi and Lundvall, 2001; Lundvall and Borrás, 1999), the RIS emphasizes the importance of regional authorities in constructing and supporting systems at a local level (Asheim et al., 2003).[4] The role of the state in regional systems of innovation has been extensively discussed, particularly in the so-called 'Italian district literature'. While there are different positions within this literature, Beccatini's (1990) only pays scant attention to the state, while Bagnasco (1988), Brusco (1982) and Trigilia (1990) in particular have written extensively about the state. Most underline the centrality of the local state (not the national state) in supporting interactive learning and facilitating innovation and how it comes to represent local interests as a whole, mediating between small entrepreneurs, workers and artisans.

Uniting most RIS researchers is a disbelief in the efficiency of markets as mediating in the transactions that are conducive to innovation. In a detailed investigation of the majority of Asian countries, Lundvall et al. (2006) concur, but nevertheless emphasize that the state cannot *a priori* be allotted a developmental role. Yet Lundvall et al. (2006) also find that in nearly all the cases of successful development in Asia the states have played a central role; in particular regional governments have shown to be central actors in the development of RISs.[5] Thus the following contrasting hypothesis can be deduced:

H5: Regional innovation policy or initiatives (that is, state intervention) are central elements for upgrading firms' technological capabilities.

6.3 Assessing technological capabilities in firms and regional systems of innovation: a new method

6.3.1 Developing the method

This section aims to provide a methodological framework to assess the technological capabilities of firms and regions systematically. It draws on the literature on systems of innovation and technological capabilities to develop a new method that integrates micro- and meso-level factors.

To study regional systemic innovation capabilities, the basic elements need to be identified: the components, their attributes or functions, and their relationships.[6] Although private firms constitute the main component of regional technological capabilities, at the meso-level many other types of actors interact with each other within a specific socio-economic and institutional framework: universities, public research centres, government, industry associations, among others, as we have discussed earlier. Depending on the aims of the research, it is possible to emphasize the role of one component, but a meso-level analysis implies a systemic approach. For example, in FDI-led, high-technology manufacturing industries in less advanced countries, TNCs might be critical to the creation of technological capabilities. Their interactions with and the indirect impact on the other components in the regional system are crucial. TNCs might have an effect on host economies through a wide array of formal and informal mechanisms such as technical assistance to local companies, knowledge and skills acquisition by local personnel working for the TNCs and imitation of new technologies by locally-owned firms.[7] We might expect that there are some important learning processes that are external to the firm and have to do with its relationships with other components in the system. Even large TNCs need to interact with and tap into resources from the local economy. In addition, absorption, adaptations, improvements and retention of foreign technology are not automatic and costless processes.

Domestic firms and innovation-oriented organizations must engage in deliberate and integrated efforts and devote substantial resources to start up and sustain a gradual process of knowledge accumulation, conducive to indigenous capability-building (see among others, Young et al., 1994; Hobday, 1995; O'Donnell and Blumentritt, 1999; Narula, 2001).

Table 6.1 presents a taxonomy to assess regional systems based on their technological capabilities.[8] The columns list the main components of the system, while the rows describe the capability level – advanced, intermediate and basic – for each component. The capability level of each component is given by its relationships with other components, and the attributes of both components and relationships. The matrix does not claim to define the optimal role of each component, but rather to identify different levels of capabilities. This tool is useful in so far as it facilitates a structured and systematic comparison between regions.[9] The basic level portrays a region with, technologically speaking, weak actors, while the advanced level describes a mature regional innovation system in terms of both relationships and attributes. It is important to acknowledge that this taxonomy might be a simplification of the components, attributes and relationships of an RSI, but it is a useful tool with which to assess and compare systems of innovation systematically.

Information to test the hypotheses presented in the previous section, making use of Table 6.1, consists of original data collected in two Mexican regions – Jalisco and Baja California, through a comprehensive survey undertaken in 2004. The firm-level survey inquired into firms' level of technological capabilities, as well as their interactions with the other components of the regional innovation system. This provides the input for columns 1 and 2 of the table and for the quantitative analysis discussed in this chapter. Information to assess technological capabilities of the other organizations in the system was collected through semi-structured interviews with key personnel of the other regional actors, as well as the analysis of existing statistics and secondary literature.

The first two columns in Table 6.1 display the two main components of the regional innovation system: foreign subsidiaries and locally-owned firms. Firms' technological capabilities are assessed, in turn, using firm-level information according to Table 6.2. Firm-level technological capabilities involve knowledge and skills, both codified and tacit, and there is no single variable that summarizes and captures their complex nature.[10] Based on the distinction between capabilities and competences,[11] outcome-related variables, such as the introduction of new products or improvements to existing equipment, are used to evaluate technological capabilities. Two types of technological capabilities are distinguished: a) process and production organization: and b) product-centred.[12] The latter

Table 6.1 Regional technological capabilities

Components/ Level	Foreign subsidiaries	Local firms	Universities and technical education centres	Public research centres	Public sector	Private organizations
Advanced	– Advanced technological capabilities within foreign subsidiaries – Strong backward linkages and integration with the local economy – Abundant knowledge flows from foreign subsidiaries to the other components of the regional system (both research- and teaching-oriented) - Complementarity and strong linkages with	– Advanced technological capabilities within local firms – Local firms design and manufacture final goods and components to be sold in the local market and abroad – Strong research-oriented linkages with other components of the system	– Large number of universities and technical education schools offering highly-qualified and specialized scientists, engineers and technicians (university degrees and postgraduate programmes) – Rapid response to changes in technologies, and even anticipation of those changes – Strong basic	– Several sector-oriented public research centres – Formation of highly-qualified and specialized resources for the sector (D.Phil. and master's) – Abundant collaborative projects with industry – Commercialization of outputs (licences, patents, instruments, etc.) – Focus on basic and applied	– Strong S&T institutions and public offices at the regional level – Strong planning, designing and implementing of innovation-oriented initiatives – Strong coordination among public offices in charge of implementing innovation-oriented initiatives – Strong support to develop	– Sectoral industry associations with strong presence in the region – Industry associations and other private organizations provide strong support to technological capability-building – A strong group of local managers which promotes technological capability-building in the region (within foreign subsidiaries, in locally-owned

Table 6.1 (continued)

Compo-nents/ Level	Foreign subsidiaries	Local firms	Universities and technical education centres	Public research centres	Public sector	Private organizations
	local research (public and private research centres, research universities) – Strong inter-firm knowledge linkages with other foreign subsidiaries and locally- owned firms	– Joint collaboration with foreign subsidiaries in design and product development – Strong trade and knowledge linkages with other locally-owned firms (local networks)	and applied research activities – Strong research- and teaching-oriented linkages with firms, including collaborative research projects – Frequent involvement in technical assistance projects with industry	research, and significant presence of commercial-oriented activities – Frequent involvement in technical assistance projects with industry – Important number of researchers leave the centre to establish their own company (indirect spin-offs)	highly-qualified and specialized human resources – Active science, technology and innovation policies properly customized to meet the needs of the region and the sector	firms, universities, research centres) – Frequent direct participation of foreign subsidiaries personnel in regional initiatives to strengthen capabilities in local firms – Strong and abundant capital suppliers to fund innovation projects, spin-offs or start-ups.

Intermediate	– Intermediate technological capabilities within MNEs – Some backward linkages with the local economy – Teaching-related links with universities and technical education centres – Few collaborative projects with universities and research centres – Some inter-firm knowledge linkages with other foreign subsidiaries and locally-owned firms	– Intermediate technological capabilities within local firms – Local firms manufacture or assemble components mainly for foreign subsidiaries located in the region or other regions within the country – Some linkages with universities and research centres, but mainly teaching-oriented – Strong flows of technology from foreign	– Good number of universities and technical education schools offering scientists, engineers and technicians with general knowledge – Not enough specialized highly-qualified personnel – Slow response to changes in technologies (to adjust programmes and courses) – Some basic and applied research – Strong teaching-oriented links and some research-	– A few sector-oriented research centres carrying out basic and applied research which is relevant for the industry established in the region – Collaborative research projects with industry, mainly in response to the needs of firms – Formation of highly-qualified and specialized resources for the sector (D.Phil. and master's)	– Some S&T institutions and public offices at the regional level – Planning and designing of regional science, technology and innovation policies – Some of the initiatives are not implemented because of lack of resources – Reduced budget and resources to promote innovation in the sector	– Sectoral industry associations with strong presence in the region – Industry associations and other private organizations provide some support to technological capability-building – A group of local managers which promotes the development of the industry, working mainly in areas not directly related to innovation: infrastructure, public services, regulation, etc. – Weak and few capital suppliers to fund innovation projects, spin-offs or start-ups.

Table 6.1 (continued)

Compo-nents/ Level	Foreign subsidiaries	Local firms	Universities and technical education centres	Public research centres	Public sector	Private organizations
		subsidiaries to local firms – Weak local trade and knowledge networks	oriented links with firms			
Basic	– Basic technological capabilities within MNEs – Poor backward linkages with the local economy (enclaves) – Limited knowledge flows from MNEs to the other components of the regional system	– Basic technological capabilities within local firms – Very few local companies supplying services and indirect goods to foreign subsidiaries – Weak or non-existent	– Few universities and technical education schools – Lack of sectoral specialization – Weak or non-existent sector-oriented research – Limited teaching-oriented links with industry,	– Few, or even lack of, public research centres – Weak or non-existent linkages with industry – Strongly focused on basic research without commercial applications	– Weak, or even lack of, regional S&T institutions or public offices; weak or non-existent coordination among public offices – Very few, or even lack of, science, technology and innovation policies to meet	– Sectoral industry associations with weak presence in the region – Industry associations are mainly oriented to provide legal or administrative advice (few or non-existent activities to promote innovation in the sector) – Weak

	links with the rest of the system – Limited flows of technology from foreign subsidiaries to local firms	and lack of research-oriented linkages		the needs of the region and sector – Limited or non-existent budgets to promote innovation in the sector – Poor involvement of industry, private organizations and academia in the formulation of public policies	coordination among the sectoral private organizations – Lack of capital suppliers to fund innovation projects, spin-offs or start-ups.

Source: Padilla-Pérez (2008b).

Table 6.2 Firm-level technological capabilities

Types of capability **Levels of capability**	**Process and production organization**	**Product-centred**
Basic	– Sub-assembly and assembly of components and final goods – Minor changes to process technology to adapt it to the local conditions – Maintenance of machinery and equipment – Production planning and control – Efficiency improvement from experience in existing tasks	– Replication of fixed specifications and designs – Minor adaptations to product technology driven by market needs – Routine quality control to maintain standards and specifications
Intermediate	– Manufacture of components – Improvement to layout – International certifications (ISO 9000) – Introduction of modern production organizational techniques (e.g. just-in-time, total quality control, etc.) – Automation of processes – Flexible and multi-skilled production – Selection of technology (capital goods)	– Product design department (design for manufacturing) – Development of prototypes – Improvement of product quality
Advanced	– Own-design manufacturing – Major improvements to machinery – Development of equipment – Development of new production processes – Development of embedded software – Radical innovation in organization – Process-oriented R&D	– Development of new products or components – R&D into new product generations – Research into new materials and new specifications

Source: Padilla-Perez (2008b), based on Lall (1992), Bell and Pavitt (1995), and Ariffin and Figueiredo (2003).

relates to the knowledge and skills needed to produce existing goods and to carry out technological product innovations. In turn, process and production organization capabilities are the knowledge and skills needed to operate production processes efficiently and to create new or significantly improved processes. They comprise the knowledge needed to use, improve or innovate machinery and equipment on the one hand, and to implement, modify and create new methods of production organization on the other. The use of advanced management techniques is included here within process and production organization capabilities.

Firm-level capabilities are also classified into three levels – basic, intermediate and advanced – according to their technological complexity.[13] This classification aims to differentiate between production capabilities (to produce goods using existing technologies) and innovation capabilities (to generate and manage technical change). It follows that there will be industrial differences in the specific capabilities to consider at each level. The taxonomy presented here has been customized for sectors such as the electronics industry, characterized by great flexibility to decompose the value chain across national borders, high R&D expenditures and widespread use of complex production organization techniques.[14]

At the firm level, the questionnaire collects information both on the level of technological capabilities in the firm and on the determinants of technological capabilities (internal and external). The potential factors associated with technological capabilities are summarized in Table 6.3. This does not claim to be an exhaustive list, but on the basis of the existing literature[15] – and taking into account the characteristics of the phenomenon studied – the most important are included. The factors were divided into two: internal and external to the firm, and included all factors related to the hypotheses presented above (interactions with local organizations, government support, exports to the world market, and so on).

As for the other components of the system, the third column in Table 6.1 deals with universities and technical education centres and their interaction with the industry. For the purpose of the methodology that we are proposing here, it is important to remember that this research focuses only on those departments or units, within each component, directly related to the studied sector. For instance, when a university or technical education school is analysed, it focuses on the engineering departments and units directly related to the studied sector.

The fourth column in Table 6.1 presents the attributes and relationships among public research centres. R&D activities can be conducted in research universities, research laboratories in private firms or public research laboratories. Research centres conduct diverse activities – such as basic and applied research, development of prototypes, formation of

Table 6.3 Potential factors associated with technological capabilities at firm level

Variable	Definition
Internal to the firm	
Age	Age of the plant since it was established in Mexico: 2004 minus year in which the firm was established.
Exports	Percentage of total production exported.
Growth	Employment growth between 2002 and 2004.
Human capital: – Direct/indirect – Unqualified/qualified	Two indicators to measure human capital: – Direct over indirect employees: (blue collar workers) / (supervisors + technicians + engineers + administrative personnel). – Unqualified personnel over highly qualified personnel: (technical education + high school + primary school + no education) / (postgraduate degree + university degree).
Ownership	A binary variable that takes the value 0 if the firm is foreign-owned and 1 if it is locally-owned.
Size	Number of employees in 2004.
Training expenditures	Average number of hours per employee per year.
External to the firm	
Source universities	A binary variable that takes the value 1 if the plant has used universities as a source of technology and 0 otherwise.
Source research centre	A binary variable that takes the value 1 if the plant has used research centres as a source of technology and 0 otherwise.
Number of sources	A variable summarizing the total number of external sources of technology used by the firm. It corresponds to the simple sum of sources, and has a maximum value of 11 and minimum of 0. The sources of technology are: suppliers of equipment and inputs, public research centres, universities, recruitment of highly-qualified personnel, licensing, clients, competitors, consultancies, fairs and exhibitions, industry associations, and other.
No. links universities	A variable summarizing the total number of different links that the firm has with local universities. It represents the simple sum of links, and has a maximum value of 5 and minimum of 0. The links include: training, student internships, secondment or visiting programmes for professors, collaborative research projects, and other.

Table 6.3 (continued)

Variable	**Definition**
No. public initiatives	A variable summarizing the total number of different public initiatives to foster innovation or technology dissemination in which the firm has participated. It corresponds to the simple sum of initiatives, and has a maximum value of 6 and minimum of 0. The public initiatives are: training, tax incentives, funds to develop new products, technology diffusion, technology upgrading, and other.
Technology transfer	A variable summarizing the total number of different types of technical assistance that the foreign subsidiary has offered to its local suppliers and the total number of different types of technical assistance that a locally-owned firm has received from TNCs established in the region. The different areas of technical assistance considered are: product specifications, quality control, process and production organization, training of engineers and technicians, purchase of machinery and equipment, and procurement of components and raw materials. It corresponds to the simple sum of the different types of technical assistance, and has a maximum value of 6 and minimum of 0.
Region	A binary variable that takes the value 0 if the firm operates in Jalisco and 1 if it is located in Baja California.

Source: Padilla-Pérez (2008b).

highly-qualified human resources through teaching, and development of new instruments and techniques, and have a substantial impact on industrial R&D in technology-intensive industries such as electronics (Cohen et al., 2002).

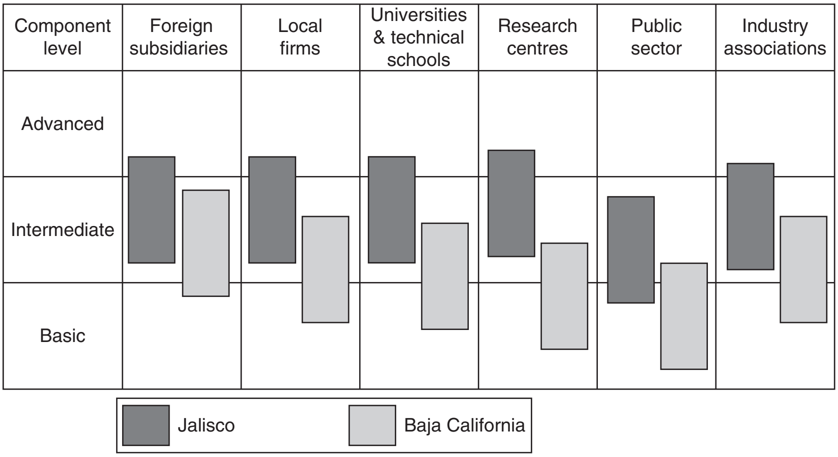
The fifth column in the table refers to the public sector. As discussed in the previous section, national and local governments play quite different roles in the development of technological capabilities. On the one hand, the public sector is responsible for creating and supervising institutions that foster technological capabilities, such as S&T law, protection of IPR, competition law, a research council or ministry of S&T, and so on. On the other hand, governments can promote the use, diffusion, improvement and production of scientific and technological knowledge through science, technology and innovation policies.[16] The qualitative and quantitative indicators used to assess the public sector must take into account that this research studies regional capabilities in developing countries, where the features of institutions and policies are different from those in developed countries.

The last column in Table 6.1 refers to industry associations and other private organizations that underpin the innovative strategy of private enterprises. These organizations may provide several types of service, such as training; diffusion of technology; services of normalization, certification and standardization; technical assistance for technological upgrading, and promotion of a culture of quality. For small enterprises in developing countries, initiatives to assist the process of international certification and training of human resources are very important. Regarding their relationships with other components of the regional system, industry associations may, for instance, foster university–industry links, assist private firms in the application and administrative processes involved in getting public support, and collaborate with the government in designing and implementing initiatives for the sector. These organizations may act as bridges between users and producers of knowledge, and are commonly known as bridging institutions.[17] Capital suppliers are included within this group of private organizations. It is crucial for a system of innovation to possess a financial system that has the resources and willingness to finance innovation.[18]

6.3.2 Analysing technological capabilities in regional systems of innovation: testing the hypotheses

Stylized facts about the regional innovation system Information collected and analysed using the methodology presented above allows the researcher to classify the different components of the system according to a scale from basic to advanced capabilities. As stated above, the methodology was applied to two Mexican regions, Jalisco and Baja California. The comparison of the results for the two regions is depicted in Figure 6.1. As will be discussed throughout the empirical evidence, Jalisco possesses more advanced technological capabilities in all the components of the system.

Before testing the hypotheses, it is important to summarize some characteristics of Baja California and Jalisco that are relevant for the analysis. Baja California is located in northern Mexico, at the border with California, United States. Its total population in 2005 was around 2.5 million inhabitants who are heavily concentrated in two border cities:



Source: Padilla-Pérez (2008b).

Figure 6.1 Regional technological capabilities: comparison between Jalisco and Baja California

Tijuana and Mexicali. Along with other northern border states, it has a strong manufacturing industry which represents 19 per cent of total GDP of the state. Jalisco is located in central Mexico, and its total population in 2005 was around 6.5 million inhabitants. The metropolitan area of the capital (Guadalajara) contains 55 per cent of the state's population. In terms of development, Baja California and Jalisco have similar indicators. GDP per capita for the former was $US 10 291 in purchasing power parity (PPP) in 2002 and for the latter, $US 8146 (UNDP, 2005). The latest Human Development Index (HDI)[19] developed by the UNDP ranks these states similarly: 0.8233 in Baja California and 0.8007 in Jalisco (UNDP, 2005).

The information to assess the first two components comes from the firm survey applied to 80 firms located in the studied regions. Additionally, 30 semi-structured interviews were conducted with key innovation actors in the system of innovation. The firm questionnaires aimed to collect two main types of firm-level information: indicators related to technological capabilities, and factors potentially associated with technological capabilities. As a first step, it was necessary to identify the relevant population, since there was no list that comprises all the electronics firms in each state.[20] Two criteria were used to classify firms in order to have a representative sample: type of firm and origin of capital.[21] The 36 firms interviewed in Jalisco (of which 55 per cent were foreign-owned) represented 82

Table 6.4 Firm-level technological capabilities in Jalisco and Baja California

	Jalisco			Baja California	
	Product-centred	Process		Product-centred	Process
Advanced	38%	25%	Advanced	4%	11%
Intermediate	17%	52%	Intermediate	21%	61%
Basic	45%	23%	Basic	75%	27%

per cent of the relevant population and had altogether 26 993 employees at the end of 2004. In Baja California the sample included 44 firms (72 per cent foreign-owned), representing 24 per cent of the population and with an overall employment of 40 621.

In Jalisco, both foreign subsidiaries and locally-owned firms had higher technological capabilities than those in Baja California. In Jalisco, 45 per cent of interviewed firms had basic product-centred capabilities, 17 per cent intermediate and 38 per cent advanced, while 23 per cent had basic process and production organization capabilities, 52 per cent intermediate and 25 per cent advanced (see Table 6.4). Only 4 per cent of interviewed firms in Baja California had advanced product-centred capabilities, while 75 per cent of them had basic capabilities. On the other hand, 27 per cent of interviewed firms had basic process capabilities, 61 per cent intermediate and 11 per cent advanced.

Testing the hypotheses To test the hypotheses, two complementary analyses were made. First an econometric analysis of the main factors associated with technological capabilities at firm level. Second, the econometric analysis was complemented by information collected from semi-structured interviews with other actors in the regional system of innovation.

As for the econometric analysis, the following model was proposed:

$$TC_i = \beta_0 + \beta_1 FA_{1i} + \ldots + \beta_n FA_{ni} + \alpha_1 R_y + \varepsilon_i;$$

where TC_i is an index of technological capabilities in firm i; FA_{xi} are firm-specific factors associated with technological capabilities (the number of factors ranges from 1 to n); R_y identifies the region in which the firm is established and is a binary variable since the fieldwork collected empirical evidence on two regions; and ε_i is the error term.

The technological capability index compares capabilities across firms using systematic criteria to classify or rank them. Its categories can be ranked from low to high, but the distances between adjacent categories are unknown, that is, the index comprises relative values. Consequently, it is argued that the index should be treated as an ordinal variable.[22] Table 6.5 summarizes the results for the whole sample (that is, the 80 interviewed firms). The interpretation of the results will be done for each hypothesis.

Goodness of fit for this cross-sectional model and sample size was good. The independent variables explain 51.1 per cent of the variation in overall technological capabilities, 46.9 per cent of process capabilities and 64.5 per cent of product capabilities. The difference between -2LL intercept and -2LL final was always significant at the 0.01 level. All regressions met the parallel regression assumption.

> *H1:* There is a direct relationship between firms' advanced capabilities and well-functioning RISs (that is, we expect firms in RISs displaying a high degree of integration and interaction to have more advanced capabilities).

The econometric results presented in Table 6.5 lead us to accept hypothesis 1. First, firms that use external sources of knowledge (such as research centres, clients and suppliers) have on average higher process technological capabilities. Second, firms that interact with research centres and universities in the studied regions in Mexico have on average higher product-centred capabilities.

When considering the region where the firm is established, the percentage of positive answers for all potential external sources of knowledge (suppliers of equipment and inputs, public research centres, universities, recruitment of highly-qualified personnel, licensing, clients, competitors, consultancies, fairs and industry associations) was always higher for Jalisco than for Baja California, showing the stronger isolation, in technological terms, of firms in the latter region. That is, firms in Baja California rely more on suppliers, clients and their own headquarters, while in Jalisco they are more open to interact with local organizations. The difference between the two regions was especially noticeable for universities: 55 per cent of interviewed firms in Jalisco said they used universities as a source of technology, but only 11 per cent of firms in Baja California said they did so (more about universities below, see Table 6.6). Links among firms in both regions were important but mainly related to the coordination of manufacturing activities and outsourcing.

The additional information collected through the semi-structured interviews with other regional actors also confirms a higher degree of maturity of the RISs in Jalisco compared to Baja California. For instance, industry associations and other private organizations in Jalisco played an active

Table 6.5 Factors associated with technological capabilities: the sample

Variables	**Dependent variable Coefficients (standard errors in brackets)**		
	TC Overall	**TC Process**	**TC Product**
Age	0.003	0.022	0.004
	(0.018)	(0.341)	(0.043)
Exports	–0.014***	0.016*	–0.054***
	(0.005)	(0.010)	(0.013)
Growth	–0.283**	–0.885	–0.390
	(0.136)	(0.275)	(0.351)
No. links universities	0.139	–0.020	0.385
	(0.166)	(0.329)	(0.383)
No. public initiatives	–0.027	–0.885***	0.546
	(0.154)	(0.323)	(0.472)
Region (=Jalisco)	0.124	0.947	–1.095
	(0.366)	(0.746)	(0.676)
Size	0.368**	1.554***	–0.265
	(0.155)	(0.398)	(0.362)
Source research centres (=No)	–0.865**	–	–2.229**
	(0.371)		(0.899)
Training expenditure	0.138	–0.125	0.325
	(0.138)	(0.262)	(0.321)
Unqualified/qualified	–0.025**	–0.044*	–
	(0.012)	(0.025)	
Number of sources	–	0.351**	–
		(0.163)	
Direct/indirect	–	–	–0.288**
			(0.145)
	Model fitting information -2LL intercept only: 226.41 -2LL final: 173.54 Significance: .000	*Model fitting information* -2LL intercept only: 160.19 -2LL final: 118.27 Significance: .000	*Model fitting information* -2LL intercept only: 150.73 -2LL final: 86.96 Significance: .000
	Goodness of fit measure Pseudo R^2 (Nagelkerke): 0.511	*Goodness of fit measure* Pseudo R^2 (Nagelkerke): 0.469	*Goodness of fit measure* Pseudo R^2 (Nagelkerke): 0.645
	Parallel regression assumption met at 0.079	Parallel regression assumption met at 0.386	Parallel regression assumption met at 0.999
	Ordinal probit regression	Ordinal logit regression	Ordinal logit regression

Note: * Significant at the 0.10 level, ** Significant at the 0.05 level, *** Significant at the 0.01 level.

Table 6.6 Sources of technology (percentage of positive answers)

Source	Jalisco	Baja California
Suppliers of equipment and inputs	89	82
Public research centres	33	14
Universities	55	11
Recruitment of highly-qualified personnel	83	55
Licensing	19	9
Clients	81	59
Competitors	47	45
Consultancies	50	32
Fairs, exhibitions	53	41
Chambers of commerce and industry associations	44	31

role in promoting the development of the electronics industry in the region. Moreover, personal networks had also been very important in Jalisco. The role of Mexican subsidiary managers and other managers in key positions within foreign subsidiaries in Jalisco is relevant in explaining the differences in capabilities in the two regions. Of the interviewed foreign subsidiaries in this region 86% were managed by a Mexican national. Mexican managers of foreign subsidiaries had had a crucial role in attracting new production lines and, more importantly, new technologies and higher value-added activities to the Mexican firm. Face-to-face interviews with subsidiary managers highlighted that subsidiary evolution, in terms of more technologically complex activities, had been a long and slow process. This process had been accomplished mostly by the activities of Mexican subsidiary managers in bargaining with and persuading parent companies that Mexico, and particularly Jalisco, had the capacities to take on and successfully perform new and more complex activities.[23] Subsidiary and other senior managers also participated actively in industry associations. Some of them met frequently with the objective of improving the competitiveness of the electronics industry in Jalisco. They had launched a series of coordinated actions in areas such as education and technology, infrastructure, and improvement of public regulation.

In sum, the systematic assessment of regional technological capabilities provides evidence to accept hypothesis 1. Firms in RISs displaying a high degree of integration and interaction perform best. A central factor that explains different firm performance (in terms of technological capabilities) in Baja California and Jalisco is stronger relationships (as well as the type of relationship) among the components in the latter. Firms not only interact with universities and research centres more frequently in Jalisco, but also research-oriented links (such as technical assistance and research collaborative projects) are more common. In the same line, firms in Jalisco carry out coordinated actions – with other firms, academia and local government – in areas such as education and technology, infrastructure and improvement of public regulation.

> *H2:* The interaction between foreign subsidiaries and locally-owned firms is important to develop advanced technological capabilities in RISs in developing countries, yet it is not an automatic process.

To unpack the relationship between foreign subsidiaries and local firms the survey sample was divided by origin of capital[24] and new variables collected through the firm-level survey were introduced in the regressions:

- Purchase local (only for TNC subsidiaries): a binary variable that takes the value 1 if the foreign subsidiary has purchased products or services from local companies, and 0 otherwise (either direct or indirect goods).
- Previous experience (only for locally-owned firms): a binary variable that takes the value 1 if the owner or founder of the locally-owned firm had previous experience as an employee or supplier with TNCs before setting up his/her own firm, and 0 otherwise.
- Knowledge acquisition from TNC (only for locally-owned firms): a variable summarizing the total number of different types of knowledge that the owner or founder of the locally-owned firm acquired from his/her previous experience with TNCs, and he/she was currently using in his/her firm. It represents the simple sum of types of knowledge, and has a maximum value of 3 and minimum of 0. The different types of knowledge are: product-centred technology, process and organization production technology, and market knowledge.

Knowledge acquired by local entrepreneurs through their previous experience with TNCs was positive and significantly associated with advanced technological capabilities (see Table 6.7).[25] This was one of the main impacts that foreign subsidiaries were expected to have in host regions: local engineers or business administrators who, using knowledge acquired from foreign subsidiaries, set up their own firms. These entrepreneurs worked as engineers or administrative personnel in foreign subsidiaries active in the region. Others supplied services such as technical assistance or commercialization of final goods. As for the other two variables (purchase local and previous experience), two factors help explain their lack

Table 6.7 Factors associated with technological capabilities: locally-owned firms[a]

Variables	**Dependent variable coefficients (standard errors in brackets)**
	TC product
Exports	−0.067 (0.022) ***
Knowledge from TNC	1.513 (0.654) **
Number of sources	0.213 (0.326)
Training expenditure	1.971 (0.732) ***
Model fitting information	
-2LL intercept only: 55.64	
-2LL final: 27.65	
Significance: .000	
Goodness of fit measure	
Pseudo R^2 (Nagelkerke): 0.740	
Parallel regression assumption met at 0.498	
Ordinal logit regression	

Notes:
* Significant at the 0.10 level, ** Significant at the 0.05 level, *** Significant at the 0.01 level.
[a] The correlation among independent variables is higher than in the whole sample. To prevent multicollinearity, this final specification does not include highly correlated variables.

of significance in the regression: 98 per cent of foreign subsidiaries interviewed purchase goods from locally-owned firms (mainly indirect goods),[26] and almost all of them offer technical assistance to their suppliers. Thus, they transfer technology to local firms independently of their technological capabilities. Dummy variables for each type of technology transfer were introduced, but they were not significant. Second, locally-owned firms operating in the electronics industry receive technology from TNCs, but its type and complexity was relatively homogeneous among firms interviewed and was not significantly associated with advanced capabilities.

The qualitative analysis allows us to establish that interaction between TNCs, and locally-owned and local organizations is important in developing advanced technological capabilities (H2). The additional information collected through the interviews with other actors in the system also provides interesting information. The two regions studied are interesting case studies of two different types of global–local interactions and the related outcomes in terms of regional capability-building. Almost 40 years after the first foreign subsidiary active in the electronics industry was established, Baja California has developed limited technological capabilities. Foreign subsidiaries in Baja California operate as enclaves: they import all, or almost all, of their inputs and intermediate products; forward and backward linkages with local firms are limited or non-existent; and links with local organizations such as universities and research centres are weak.

As regards Jalisco, at the time the fieldwork was conducted a significant production and technological transformation was taking place, through a virtuous circle between foreign subsidiaries and local agents. On the one hand, foreign subsidiaries had moved towards higher value-added activities and increased their interactions with local actors. On the other, the presence and activities of foreign subsidiaries have stimulated and supported the creation of better human resources and innovation-oriented organizations. By a process of cumulative causation, higher regional technological capabilities have encouraged foreign subsidiaries to transfer more technologically advanced activities to firms in the region.

> *H3*: Export to the world market stimulates upgrading in firms located in RISs in developing countries (as more advanced users are located overseas).

As for the third hypothesis, Table 6.5 shows that the coefficient of *exports* is negative and significant for overall and product capabilities. The sign of the coefficient contradicts H3 and economic theory, which assert that exports, through access to new and bigger markets, generate economic incentives for increased innovative effort. Firms in Jalisco have on average higher product capabilities, but export a lower proportion of their production than firms in Baja California, which are more integrated into the US economy.

The negative relation between exports and product capabilities is especially strong for small, knowledge-intensive firms in Jalisco, which are engaged in product design, product development and R&D, but sell most of their products (or services) to MNEs established in the same or other regions within Mexico. In contrast, *exports* are significantly and positively associated with process capabilities. In general, process capabilities in the electronics industry are associated with large plants,[27] which possess the financial and human resources to implement complex production organization techniques and undertake long and costly certification processes. Large firms, which are mainly foreign subsidiaries, are more oriented to foreign markets, since they set up plants in Mexico to supply the US market. Summarizing, exports are positively associated with advanced process technology, but not necessarily with product-centred technologies.[28]

Table 6.8 University/technical education schools–industry links (percentage of positive answers)

	Jalisco	**Baja California**
Curricula updating	100	100
Student internships	100	100
Donation of equipment	100	100
Training courses	100	100
Secondment programmes for professors	50	0
Basic research*	67	25
Applied research*	100	75
Collaborative research projects*	67	0
Technical assistance	50	60
Participation in public initiatives to promote interaction with industry	100	29

Note: * The percentage of positive answers to basic research, applied research and collaborative research projects takes into account only universities, since technical education schools in the studied regions are supposed to be purely teaching oriented (according to the activities set out in their charter).

H4: Universities in developing countries are expected to play mainly a role of provision of highly qualified human capital.

As presented in Table 6.5, the coefficient of *research centres as a source of technology* is negative and significant for overall and product-centred capabilities. *Source research centres* and *number of links universities* are highly correlated; when the former is dropped from the regression, the latter is significant and positive for product-centred capabilities. Firms with advanced capabilities, in particular product-centred capabilities, use universities and research centres as a source of technology. Advanced product-centred capabilities were less common among the interviewed firms, and on average these firms used universities as a source of knowledge. The interviews with representatives from universities and research centres established in the two studied regions showed that collaborative research with firms were heavily concentrated on product-centred technologies. Process-related knowledge came from other sources of technology such as suppliers of machinery and equipment and consulting firms.

Table 6.8 summarizes the results from the interviews with innovation-oriented organizations. The universities in Jalisco that were interviewed carried out applied research related to the electronics industry and two were also involved in basic research. These latter two had also been involved in collaborative research projects with industry. In Baja California, three out of four of the universities that were interviewed in Baja California carried out applied research related to the electronics industry, but not necessarily to the activities of firms in the region; only one university did basic research. None of these universities had been involved in collaborative research projects with industry. The applied research that was conducted was mostly related to projects with educational objectives.

Each region had two research centres specialized in or conducting research on areas related to the electronics industry, all of which were interviewed. In Baja California, both centres offer Master's and Ph.D. degrees and are heavily oriented to basic research. Their interactions with industry were limited and almost restricted to offering customized training courses. In clear contrast, public research centres in Jalisco carry out basic and applied research, and are involved in collaborative research projects and technical assistance with local firms (mostly foreign subsidiaries, but also with some locally-owned). Both were founded as the outcome of the interaction between TNC foreign subsidiaries and Mexican universities, and one of them (CINVESTAV)[29] offers postgraduate programmes in electronics.

So, we can also conclude that firms located in RISs with strong presence of universities and public research centres perform better in terms of technological capabilities. The interaction between firms and universities and research centres could lead to a virtuous circle of technological capability-building. On the one hand, research laboratories within universities or public research centres act as a conduit for technologies from foreign subsidiaries. Joint research projects with firms provide research labs (in universities and public research centres) with financial resources and state-of-the-art technologies, which are crucial given their limitations to access both (resources and technologies). On the other hand, research labs offer high value-added services to local firms and foreign subsidiaries, anchoring the latter to the host region and assisting the former to develop their own technologies. Universities and research centres in Jalisco had greatly benefited from the interaction with TNC foreign subsidiaries established in the region, and the latter had moved to more knowledge-intensive activities since they had found highly-qualified human capital and specialized organizations that supported their technology strategy. The interaction with the universities and research centres has a positive impact on product-centred capabilities.

> *H5:* Regional innovation policy or initiatives (that is, state intervention) are central elements for upgrading firms' technological capabilities.

In order to obtain more robust results to test hypothesis 5 (the role of regional innovation policy), the variable *number of public initiatives* in

Table 6.5 was disaggregated by type of initiative, and a dummy variable was introduced to examine whether a particular initiative has a positive impact on firm-level technological capabilities. The five public initiatives were: training, tax incentives, funds to develop new products, technology diffusion and technology upgrading. The coefficient was significant only for *government new products* (use of public funds to develop new products) for product-centred capabilities. As for process capabilities, these are more homogeneous in the sample, since the electronics industry operates under high international standards. Government support seems not important to explain the type of process technological capabilities possessed by firms interviewed for this research. Table 6.9 summarizes the results, only for the regression in which the coefficient was significant (TC product).

As regards the comparison of the two regions, the information collected from other regional actors revealed important differences between them. The local government in Jalisco had an office in charge of science and technology policy (State Science and Technology Council of Jalisco). This council coordinated a series of public initiatives such as public funds for R&D, promotion of university–industry links, technology dissemination and human resource formation. It had a well-developed programme to foster innovation in manufacturing, with specific initiatives for the electronics industry, although it should be acknowledged that the local government budget was limited and many initiatives in the programme described above had not been implemented due to lack of resources. Baja California also had a programme of science and technology policy, but it does not have any specific governmental agency that coordinates its implementation. Local policies to support innovation and formation of human resources were scant and spread across different local ministries, such as education and economic development. In addition, there was a shortage of public funds to support innovation. As a direct consequence, for firms in Baja California it is harder to find government support.

The comparison between Baja California and Jalisco shows that regional innovation policy is a central element to building technological capabilities in developing countries (H5). Strong institutions and an active local public sector are central to creating the framework for and fostering innovation among firms and organizations in the region. Some of the attributes present in Jalisco, but not in Baja California, are illustrative of the importance of institutions and an active public sector: a ministry that coordinates industrial public policy; a public office in charge of science, technology and innovation policy; public initiatives aimed at fostering innovation in the electronics industry including dissemination of technology, promotion of university links and technological upgrading, and formation of human resources, among others.

Table 6.9 Factors associated with technological capabilities: the impact of public policy

Variables	**Dependent variable coefficients (standard errors in brackets)**
	TC product
Age	0.039 (0.047)
Direct/indirect	−0.989** (0.465)
Exports	−0.070*** (0.016)
Government new products (=No)	−3.449*** (1.318)
Growth	−0.927 (0.581)
No. links universities	0.264 (0.400)
Number of sources	−0.272 (0.197)
Region (=Jalisco)	−1.571* (0.938)
Size	−0.448 (0.393)
Source research centres (=No)	−3.431** (1.097)
Training expenditure	0.376 (0.370)
Model fitting information	
-2LL intercept only: 147.76	
-2LL final: 77.96	
Significance: .000	
Goodness of fit measure	
Pseudo R^2 (Nagelkerke): 0.696	
Parallel regression assumption met at 0.624	
Ordinal logit regression	

Note: * Significant at the 0.10 level, ** Significant at the 0.05 level, *** Significant at the 0.01 level.

6.4 Conclusions

The chapter shows that RSIs in developing countries, commonly considered as emerging or incomplete systems, share central characteristics of RSIs in developed countries. RISs specific trademark is the importance of the interaction between the components of the system. Hypothesis 1 tested the relevance of the integration of the system and the interaction among its components. Firms within RSIs displaying a high degree of integration and interaction have on average more advanced technological capabilities. In high-technology industries (such as electronics) in developing countries, suppliers and clients (of which most are foreign firms) are a central source of knowledge, but links with local organizations are also important in developing technological capabilities. In addition, the empirical evidence illustrates the relevance of personal networks, and in particular the role of general managers as promoters of local industry and disseminators of imported technologies. At the same time, foreign subsidiaries, through backward linkages and links with local organizations, transfer knowledge to the host region and contribute to the development of firm and regional technological capabilities (hypothesis 2). However, exports are not significantly associated with advanced product-centred capabilities (hypothesis 3), since the knowledge needed to develop those capabilities can be sourced from foreign firms established in the region, local organizations or suppliers of equipment and inputs, but not necessarily from the exposure to international markets.

Universities and research centres in developing countries play an important role as providers of highly-qualified human capital, as in developed countries. Yet in emerging or incomplete RISs, those organizations may also play a significant role as providers of new industry-specific knowledge (hypothesis 4). However, it is important to acknowledge that the type and intensity of interactions may be weaker in developing countries. For instance, university–industry links might be more oriented to teaching-related activities, such as curricula updating and student internships, and only a reduced number of firms may have the interest and capacity to engage in joint research projects with universities and research centres.

Thus, the empirical evidence stresses the importance of long and sustained efforts by all the components of RISs. The same industry in the same country may show a radical different performance, depending on the characteristics of the local systems. The electronics industry in Jalisco, at the time fieldwork was conducted, was engaged in a virtuous circle of capability-building, whereas Baja California could be described as an enclave economy. In this context, regional innovation policy is a central element for firm and regional capabilities in a developing country (hypothesis 5). Strong institutions and an active public policy are crucial for fostering innovation.

Hence, the overall empirical findings of this study suggest that the conceptual and related policy challenges associated with conceptualizing and constructing regional innovation systems in developing countries are smaller than assumed in the literature. Yet our research needs to be complemented by other systematic econometrical empirical studies. Data are also likely to reflect spatial–temporal specificities that need to be addressed; this calls for larger comparative studies across time, industries and regions/countries. Finally, RIS research concerning developing countries – as is also the case in our study – needs to pay more attention to indigenous innovations originating outside formal knowledge-creating industrial settings such as firms and universities. To our knowledge there have been no RIS studies concerned with, for example, innovations occurring in the informal economy or the rural communities. These innovations might not become institutionalized standard innovations but might hold important roles for reduction of poverty. Yet we know almost nothing about the nature of these innovations, how they disseminate and which type of innovation systems can support them. In this sense, innovation systems literature needs to start addressing the question of the direction of change, that is, what is being innovated and for whom, instead of using innovation and standard economic performance measures (that is growth, competitiveness), to gain a stronger relevancy for coping with problems related to development.

Notes

1. For example, South Korea has employed a state-centred model relying on a flexible 'penduling' between import-substitution industrialization (ISI) and export-oriented strategies for industrialization, and even becoming industry leaders in selected fields. Singapore, China and India have relied on FDI for their development, upgrading and innovation strategies, yet approached their home markets and applied strategies for constructing indigenous capabilities in a variety of different ways. Mexico has chosen to focus on exploiting its physical proximity to the US, and so forth.
2. However, the empirical support for this thesis on proximity and interactive learning is contested. While Jaffe et al. (1993), for example, find support for knowledge spillovers within a certain regional innovation system, other more recent studies emphasize the unequal nature of localized learning in clusters (Giuliani, 2007) and the importance of absorptive capacity.
3. The notion used is also at odds with Hayek's (1945) notion of spontaneous self-organizing systems (i.e. catallaxy).
4. For a more detailed discussion on the interaction between local and national levels of policy making, see Vang and Chaminade (2006).
5. The role of the state supporting innovation is highly contested in developing countries. As some research shows, the state might even aggravate the systemic problems, through, for example, the development of an inadequate institutional framework (or the absence of it), adverse selection mechanisms or even competing with the private actors to access scarce resources. This suggests that states – regional or national – and policy should not always be considered constitutive elements in creation of RIS in developing countries. For example, several empirical studies of Bangalore have suggested that there has not been a need for state intervention (apart from education policy) in at least the early phases of the development of the RIS (Athreye, 2005; Arora and Gambardella, 2004).
6. Carlsson et al. (2002, p. 243) define a system as 'a set of interrelated components' (that is made up of components, relationships and attributes).
7. See, for instance, Caves (1980); Grossman and Helpman (1991); Dunning (1994);
8. See Padilla-Pérez (2008b) for further details on this methodology.
9. It is important to acknowledge that this regional matrix was developed to study an FDI-led, technology-intensive industry in a developing country. The taxonomy was created on the basis of the existing literature, as recognized below, and our own fieldwork.
10. Technology capabilities at firm-level have been widely studied and are understood as the knowledge and skills needed to absorb, adapt, modify and generate new knowledge. See, for instance, Lall (1992) and Bell and Pavitt (1993).
11. Competences are understood as inputs to produce goods and services, and capabilities involve contemporaneous learning and the accumulation of new knowledge, and

the integration of behavioural, social and economic factors. See von Tunzelmann and Wang (2003).

12. Several authors have studied technological capabilities at firm level, using different classifications: production, investment, innovation, operation, acquisition, linkage, and so on. In general, these classifications aim at decomposing the constituent elements of technological activity within the firm. See, for instance, Desai (1985); Baranson and Roark (1985); Dahlman and Brimble (1990); Lall (1992); Bell and Pavitt (1995); Kim and von Tunzelmann (1998); Romijn (1999) and Viotti (2002). The classification here aims on the one hand to simplify the analysis, and on the other to distinguish between competences and capabilities.
13. The classification of technological capabilities into three levels was used by Lall (1992), Bell and Pavitt (1995) and Ariffin and Figueiredo (2003).
14. See Padilla-Pérez (2005) for further information on the electronics industry.
15. There is a myriad of studies on technical change within the firm. Some of the references to select the factors potentially associated with firm-level technological capabilities are: Nelson and Winter (1982); Dosi et al. (1990); Freeman and Soete (1997) and Romijn (1999).
16. See Dalum et al. (1992); Gregersen (1992); Mowery (1995); Freeman and Soete (1997); Dutrénit (2005), and Lundvall and Borrás (2004).
17. For more information, see Buitelaar et al. (2000); and Casalet (2000).
18. Innovation is an expensive process and significant resources must be devoted to initiate, direct and sustain it. It is also a long-term and slow process (and the resources for its support must be committed over a similarly long term) and its outcomes are uncertain (O'Sullivan, 2005, p. 240). Large firms finance internally risky investment in innovation, but small firms, especially in developing countries, do not have the financial resources to do this (Christensen, 1992; Luthria and Nabi, 2002).
19. 'The human development index (HDI) is a composite index that measures the average achievements in a country in three basic dimensions of human development: a long and healthy life, as measured by life expectancy at birth; knowledge, as measured by the adult literacy rate and the combined gross enrolment ratio for primary, secondary and tertiary schools; and a decent standard of living, as measured by GDP per capita in purchasing power parity (PPP) US dollars.' See UNDP web page: http://hdr.undp.org/statistics/indices/about_hdi.cfm.
20. See Padilla-Pérez (2008b) for further information on how the population was identified and the sample constructed.
21. Following Ernst and Kim (2002), four types of firms can be identified in the electronics industry, each with different technological characteristics: original equipment manufacturers, contract manufacturers, suppliers and design houses. The second criterion was intended to give a representative sample of foreign-owned firms and locally-owned firms and, within the former, to cover firms from different nationalities.
22. See Long (1997) for more information on ordinal variables.
23. Along the same lines, Birkinshaw and Hood (1998) argue that decisions made by subsidiary managers regarding the activities undertaken by the subsidiary are crucial to explaining subsidiary evolution.
24. The regressions for foreign subsidiaries have 53 observations, and 27 for locally-owned firms.
25. Only the results that are relevant for the analysis are reported.
26. Indirect goods are those not directly incorporated in the final good, for example: packing and wrapping products, furniture, consumable goods, labels, bags, foam, fabrics, gloves, cleaning products and paper board.
27. *Size* was significant and positive for overall and process technological capabilities.
28. Other factors such as *size*, human capital (*unqualified/qualified and direct/indirect*) and growth were also significantly associated with technological capabilities. The detailed results can be found in Padilla-Pérez (2008b).
29. Research and Advanced Studies Centre.

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Appendix

Table 6A.1 Technology capabilities indices

TC PROCESS	**Ordinal variable, maximum value = 3, minimum value = 1**
TC proc = 1	if firm *i* had not modified or adapted machinery and equipment, or had only carried out minor adaptations to the local conditions; did not operate under advanced management techniques; and had not been certified by internal standards
TC proc = 2	only if firm *i* fulfilled ALL the following: operated under advanced management techniques (at least 3 out of 5 techniques listed in the questionnaire); had been certified by internal standards; was characterized by flexible production schemes; and had modified machinery and equipment to increase efficiency
TC proc = 3	only if firm *i* fulfilled ALL the requirements in the above level (TCproc = 2) and additionally had developed new equipment and software
TC PRODUCT	**Ordinal variable, maximum value = 3, minimum value = 1**
TC prod = 1	if firm *i* received product specification from the parent company or clients and had not carried out production adaptation and modification
TC prod = 2	if firm *i* had a product design department (design for manufacturability) and had frequently modified and improved its products
TC prod = 3	if firm *i* had carried out R&D activities and had developed new or significantly improved products
TC OVERALL = TCproc + TCprod	**Ordinal variable, maximum value = 6, minimum value = 2**