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Globalisation of knowledge production and regional innovation policy: Supporting specialized hubs in the Bangalore software industry

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ABSTRACT

This paper is concerned with the changing role of regional innovation systems and regional policies in supporting the transition of indigenous firms in developing countries from competing on low costs towards becoming knowledge providers in global value chains. Special attention is paid to policies supporting the emergence and development of the regional innovation system in this transition process. Regional innovation systems in developing countries have very recently started to be conceptualised as specialized hubs in global innovation and production networks (Asheim, B., Coenen, L., Vang-Lauridsen, J., 2007. Face-to-face, buzz and knowledge bases: socio-spatial implications for learning, innovation and innovation policy. Environment and Planning C: Government and Policy 25 (5), 655–670; Chaminade, C., Vang, J., 2006a. Innovation policy for small and medium size SMEs in Asia: an innovation systems perspective. In: Yeung, H. (Ed.), Handbook of Research on Asian Business. Edward Elgar, Cheltenham; Maggi, C., 2007. The salmon farming and processing cluster in Southern Chile. In: Pietrobello, C., Rabellotti, R. (Eds.), Upgrading and Governance in Clusters and Value Chains in Latin America. Harvard University Press). A specialized hub refers to a node in a global value chain that mainly undertakes one or a few of the activities required for the production and development of a given good or service or serves a particular segment of the global market. In global value chains, firms in developing countries have traditionally been responsible for the lowest added-value activities. However, a few emerging regional innovation systems in developing countries are beginning to challenge this scenario by rapidly upgrading in the value chain. There is, however, still only a poorly developed understanding of how the system of innovation emerges and evolves to support this transition process and what the role of regional innovation policy is in building the regional conditions that support indigenous small and medium size enterprises (SMEs) in this transition process. This paper aims at reducing this omission by analyzing the co-evolution of the strategies of indigenous SMEs and the regional innovation system of Bangalore (India).

1. Introduction

In recent years there has been a blossoming interest in the rapid growth of certain regions in developing countries, particularly in China and India. These regions have become specialized hubs in global value chains providing, in some cases, knowledge-intensive goods and services whilst they appear to be rapidly moving up the global value chain. Most

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of the literature has focused on the strategy of particular firms, the vertical and horizontal links in the clusters or the determinants of the successful growth of these regions in terms of human capital endowment or export-led growth models. Yet not much attention has been paid to the role of the regional innovation system and the regional policy in supporting this rapid growth. And even less attention has been paid to the link between regional innovation systems and global value chains.

This paper is concerned with analysing the changing role of regional innovation systems and regional policies in supporting the transition of indigenous firms in developing countries from competing on low costs towards becoming knowledge providers in global value chains. Special attention is paid to policies supporting the emergence and development of the regional innovation system in this transition process. Among policy-makers and academics consensus has long suggested that innovation is a crucial factor in generating economic growth and development (Kaplinsky, 2006; Lundvall, 1992; Schmitz, 2006; Von Hippel, 1988). Innovation systems research has acknowledged this and has placed innovation at the heart of the discussion on upgrading and growth in developing countries (Giuliani and Bell, 2005; Lee and von Tunzelmann, 2004; Lundvall et al., 2006).

Most work on innovation systems suggests that the region is a key level at which innovative capacity is shaped and economic processes coordinated and governed (Chaminade and Vang, 2008; Gu and Lundvall, 2006; Schmitz, 2006; Vang and Asheim, 2006) and, as a consequence, research focused initially on the endogenous-led growth of the region, where the regions were conceptualised as self-organizing and self-containing systems. The consequence for the policy sphere was a strong focus on constructing or building self-containing regional innovation systems. While this model was initially useful to explain the growth of certain regions in the developed world (e.g. Third Italy, Silicon Valley, Hollywood and Baden-Württemberg), developing countries' experiences with self-contained systems have seldom resulted in the desired outcomes, requiring strategies combining internal and external sources of capital, technology and knowledge (Loebis and Schmitz, 2005; Pietrobello and Rabellotti, 2007; Schmitz, 2006). Instead regions are to be understood as specialized hubs in global value chains,[1] which are constituted through dynamic relations and interactions with local and trans-local organizations and firms (Amin, 2004).

Thus regional innovation systems in developing countries have very recently started to be conceptualised as specialized hubs in global innovation and production networks (Asheim et al., 2007; Chaminade and Vang, 2006; Maggi, 2007). A specialized hub refers to a node in a global value chain that mainly undertakes one or a few of the activities required for the production and development of a given good or service or serves a particular segment of the global market. In global value chains, firms in developing countries have traditionally been responsible for the lowest added-value activities.[2] This does not pose great demands on the need for a well-functioning regional innovation system as competition is primarily based on exploring low-cost factor endowments. However, a few emerging regional innovation systems in developing countries are beginning to challenge this scenario by rapidly moving up the global value chain (traditional upgrading) and/or using the competences built in the initial phases of development for shifting into related industries (functional upgrading).[3] There is, however, still only a poorly developed understanding of the *systemic propensities of the transition process* (Lundvall et al., 2006); that is, how the system of innovation emerges and evolves to support this transition process and what the role of regional innovation policy is in building the regional conditions that support indigenous small and medium size enterprises (SMEs) in this transition process.

This paper aims at reducing this omission by linking the upgrading strategy of indigenous SMEs to the emergence and evolution of the regional innovation system. In particular, we will analyse how the move towards knowledge providers requires the support of a well-functioning regional innovation system, how the system of innovation emerges and evolves with the changing strategy of the firms, and discuss the implications of this transition process for the design of regional innovation policies in developing countries. For attaining this goal the transition of Bangalore's software innovation system is analysed.

Bangalore's – together with Shanghai's – regional innovation system is among the most notable successes in reaching the goal of moving towards higher-end products (albeit still far from having succeeded in this upgrading process, as we will argue in this paper). Recent research has documented that Bangalore has become one of the most important IT clusters outside the OECD countries (Arora and Gambardella, 2004, 2005). Bangalore is also interesting as a case since it has grown basically from scratch without local (lead) users pulling the demand for technologies, almost without cooperation among indigenous firms and with weak support from the national and regional governments. But Bangalore has nevertheless managed to sustain the world's highest growth rates within the industry (Arora and Gambardella, 2004) for a decade. The combination of local high-quality education institutions and the large presence of multinationals with strong linkages with the indigenous firms – including SMEs – has supported the accumulation of competences in indigenous firms, thus setting the grounds for the emergence of a (somewhat immature) regional innovation system. While

[1] It should be noted that by 'global value chains' we wish to emphasize the global distribution of different activities of a production process. In this sense, we understand global value chains in a flexible way, closer to 'global value networks' than to the classical linear definition of global value chains (see for instance Fig. 1 below).

[2] In IT, for example, testing of software, standard programming, etc.

[3] India, for example has become a global hub for IT services and is gradually moving into pharmaceutical and biomedical research. Pakistan is starting to out-compete German manufacturers of surgical instruments, while China is rapidly accumulating competences to upgrade in different industries ranging from textiles to automotive and IT hardware.

the industrial organization of Bangalore has been dealt with in several papers, there is not yet any analysis of how the regional innovation system has evolved (and needs to evolve) to support the (further) upgrading process of the indigenous SMEs, what the caveats are for such transition, and how the government can stimulate the development of such a system.

The structure of the remainder of the paper is as follows. First, we introduce the theoretical framework—the regional innovation system (RIS), in Section 2. Special attention is paid to the systemic propensities of the RIS, that is, the critical interactive learning that takes place at regional level and how this can be adapted to the context of developing countries. The importance of these dimensions of an RIS is examined for the emergent innovation system in Bangalore in Section 3. This is followed in Section 4 by assessing the RIS as a specialized hub in developing countries in the context of globally distributed industries. Policy implications are drawn in Section 5, and the paper is rounded off with concluding remarks in Section 6.

2. RIS, interactive learning and upgrading in global value chains

The purpose of this section is to introduce the RIS concept and its particularities in developing countries, paying special attention to evolutionary aspects; that is, how the system of innovation emerges and evolves over time into a well-functioning RIS. The latter is characterised by the intensity of the interactions between the organizations located in the RIS. The nature of those interactions is discussed in detail, particularly user–producer interactions (TNC-SME) and the linkages between SMEs and the knowledge providers.

2.1. Regional innovation systems

Upgrading to higher value activities in global value chains seems possible when there is an environment that supports interactive learning and innovation. Firms' isolated efforts to make this transition tend to fail in the longer term. Activities at the higher end of the product range involve a high degree of innovation and interaction with customers, other firms and organisations. In the case of SMEs, the literature argues that the interaction best takes place with other firms and organisations co-located in the same regional area (Lundvall and Borrás, 1999). The importance of the local interactions for SMEs holds for developed (Asheim et al., 2003; Cooke and Morgan, 1998; Cooke and Will, 1999; Schmitz, 1992) as well as developing countries (Albu, 1997; Giuliani, 2004; Giuliani and Bell, 2005; Pietrobello and Rabellotti, 2007; UNIDO, 1997, 2004). Moreover, this literature explicitly finds that SMEs' external relations are more confined to the region than those of large firms (Asheim et al., 2003; Cooke and Morgan, 1998). One of the reasons for this is that SMEs are more dependent on complex, tacit knowledge and less capable of searching for and using codified knowledge. This forces them to rely more on personal ways of transferring (tacit) knowledge and on learning-by-doing and interacting as opposed to relying on globalized (and more codified) modes for knowledge acquisition.[4]

For this reason, the paper is based on the regional innovation systems (RIS) approach. Regional innovation systems can be seen as a "constellation of industrial clusters surrounded by innovation supporting organizations" (Asheim and Coenen, 2005). Thereby, the regional innovation system is boiled down to two main types of actors and the interactions between them. The first type of actors are the companies in a region's main industrial clusters, including their customers and suppliers. In this sense, industrial clusters represent the production component of the regional innovation system. In the RIS approach, industrial clusters are defined as the geographic concentration of firms in the same or related industries (Pietrobelli and Rabellotti, 2004; Porter, 1998; for a critique, see Martin and Sunley, 2003). The second type of actors, backing up the innovative performance of the first type, include research and higher education institutes (universities, technical colleges, and R&D institutes), technology transfer agencies, vocational training organizations, business associations, finance institutions, etc. (Asheim and Coenen, 2005). The knowledge creating and diffusing organizations provide the resources and services (knowledge, capital, etc.) to support innovation among the local firms.[5]

In a well-functioning RIS, proximity facilitates the circulation of knowledge and information needed for innovation. Contrary to more traditional approaches to innovation and upgrading (that focus on the acquisition of technology), an RIS approach stresses that supporting SMEs in their innovation-oriented upgrading process is a matter of not only facilitating the access to technology, but supporting interactive learning.[6] Innovation is the result of an interactive learning process stretching across firm borders (Lundvall, 1992). Interactive learning is defined as the acquisition of knowledge and competences through inter-

[4] This might be partly counterintuitive as codified knowledge appears to easier to search for, absorb, integrate and use. Yet, developing the absorptive capacity allowing for systematic search and use of codified knowledge requires significant investments and institutionalization of specific routines and management practices, which is often beyond the scope of most SMEs.

[5] The inclusion of the second type of actors represents a main difference from traditional cluster studies in developing countries. Universities and other knowledge providers are considered crucial in correcting or changing systemic failures in clusters which might prevent them from upgrading or engaging in radical innovations (Asheim et al., 2007). Traditional industrial districts and clusters research is more concerned with the propensities in local systems that support incremental innovations, thus 'Schumpeterian' systems failures are not theorized.

[6] This is different from Porter's cluster theory that mainly focuses on rivalry as the engine for competitiveness and growth in the cluster. It also runs against Malmberg and Maskell (2006) whose cluster theory mainly focuses on what they call "observability"; that is, the ability to monitor the activities of other localized producers while not necessarily interacting with them. Compared to the cluster literature, the innovation system approach particularly focuses on interactive learning activities conducive to innovation and thus growth. Yet, most important for choosing RIS vis-à-vis other competing frameworks is that it contains the most systematically developed conceptualization of interactive learning; including the link between devolution, institutions and interactive learning. Even NIS scholars have increasingly recognized the importance of regions as a central scale for economic activities (see Lundvall et al., 2006).

active collaboration with firms and knowledge providers. It is considered a function of the *soft infrastructure* (increased qualifications of the human resources, organizational capital and inclusive social capital) (Chaminade and Vang, 2006, 2008; Lundvall et al., 2006).[7] In contrast to other approaches stressing these variables, the RIS approach puts the emphasis on the *systemic dimension* of the innovation process, as the dynamic interaction between the different nodes in the system and the impact of the system's weak nodes on the dynamic efficiency of the system as a whole.

2.2. Systemic aspects of RIS: critical interactive learning paths

Well-functioning RISs are characterised by the intensity of the interactions between the different building blocks of the system. The extent to which SMEs can learn through the interaction with the local environment is a function of their absorptive capacity (Cohen and Levinthal, 1990), i.e. the ability to utilise the information and knowledge that comes from the interaction with users, other firms and/or knowledge providers (e.g. research institutions). Central to building absorptive capacity is the accumulation of human capital and other forms of knowledge. Firms need to have the necessary human capital to identify, acquire and transform the internal and external knowledge required for developing innovations,[8] especially innovations of a more radical character.

Interactive learning is considered to be dependent on social capital (Bourdieu, 1983; Coleman, 1988; Fukuyama, 1995). "Social capital refers to the institutions, relationships, and norms that shape the quality and quantity of a society's social interactions. Social capital is not just the sum of the institutions which underpin a society—it is the glue that holds them together" (World Bank, 1998). Social capital refers to both "structural social capital" and "cognitive social capital" (World Bank, 2002). Structural social capital involves "relatively objective and externally observable social structures, such as networks, associations, and institutions, and the rules and procedures they embody." Cognitive social capital comprises "more subjective and intangible elements such as generally accepted attitudes and norms of behaviour, shared values, reciprocity, and trust."[9] Unless there is a high degree of generalized social capital (i.e. non-discriminating) and a high degree of absorptive capacity cooperation, communication and thus interactive learning is usually limited (Nooteboom, 2000). In the absence of trust, the fear of opportunistic behaviour will prevent the exchange of valuable knowledge and mutual learning (Fukuyama, 1995; Maskell, 2000; Putnam, 1993). Hence unless there is a high degree of generalized social capital, interactive learning is likely to be limited or at least confined to the 'in-groups', which greatly reduces localized knowledge spillovers (Putnam, 1993; Vang and Asheim, 2006).

Interactive learning benefits from physical proximity (Gertler, 1995; Morgan, 2004) as physical proximity is considered pivotal in the emergence of the cognitive social capital (for a critique, see Amin and Cohendet, 2005). Physical proximity implies that the firms are embedded in the same institutional setting and thus share certain norms, conventions and mindsets. Hence, a shared institutional setting facilitates the transmission of complex tacit knowledge needed for innovation.

Interactive learning and thus innovation will most probably take place when both human capital and social capital are in place, as comparisons of a number of cases have shown (Chaminade and Vang, 2006, 2008). Furthermore, physical proximity might in some cases support the emergence of social capital, thus setting the grounds for interactive learning. Interactive learning can take place in the interaction with the users, with other firms in the industrial clusters or with the knowledge providers of the regional innovation system.

Innovation systems research has long emphasized the importance of *user–producer interaction* for upgrading and innovation (Castellacci, 2006; Fagerberg, 2004; Jeppesen and Molin, 2003; Lundvall, 1988; Luthje et al., 2005). The emphasis on user–producer interaction stems from the fact that innovations often occur in response to specific problems that emerge from the interaction between them. Recently, the focus has shifted towards lead users (Franke and Shah, 2003; Franke and von Hippel, 2003; Franke et al., 2005). Lead users are defined as users that perceive needs well ahead the mass market and often have developed their own innovative adaptive solutions (Jeppesen and Frederiksen, 2006).[10] Interaction with users might provide incremental innovations while interaction with lead users might be more important for more radical innovations and thus more valuable for the innovative firm. 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.[11]

[7] See Rodriguez-Pose and Storper (2006) for a detailed and critical discussion of the role of social capital, trust, etc. for economic development.

[8] Moreover, as Kaufmann and Tödtling (2002) point out, SMEs need to use the human resources more intensively than large firms in their innovation process. However, in general terms SMEs face difficulties to attract and retain qualified human resources, especially when they are competing with TNCs as in developing countries.

[9] Although these two forms of social capital are mutually reinforcing, one can exist without the other. Government-mandated organizations represent structural social capital in which the cognitive element is not necessarily present.

[10] It is beyond the scope of this paper to engage in a detailed discussion of limits to the lead-user approach but it should be stressed that lead users might suggest investments in R&D projects aimed at goals not shared by the majority of consumers; not even in the future.

[11] Additionally, the research on user–producer interaction tends to ignore that the importance and morphology of user–producer interaction is contingent on the specificities and particularities of the indigenous firms' position in the global value chain. Production of 'low-end' goods and services mainly requires a limited interaction with the users but can nevertheless serve as a competence-building phase. Production of 'higher-end' goods and services normally requires a greater degree of user–producer interaction. The move from production of low-end goods and services to high-end services is thus constrained by the lack of localised lead users in developing countries; especially for indigenous SMEs. Indigenous TNCs can compensate for this by establishing subsidiaries in close proximity

Users are not the only source of knowledge and technology for firms, although empirical research asserts that they may be the most common (Fagerberg, 2004). Interactions at local level with other firms or knowledge providers constitute other important sources of innovation and can facilitate the acquisition of knowledge and competences needed for upgrading in global value chains. The vast literature on clusters has long acknowledged the advantages of engaging in *interactive learning with other firms* located in the cluster (Malmberg and Maskell, 2004; Maskell, 2004; Piore and Sabel, 1984). As opposed to the externalities that might emerge by the simple co-location of firms in related activities in one region (Marshall, 1920), the deliberate cooperation between actors leads to increasing innovation (Nadvi and Schmitz, 1999; Schmitz, 1995).[12] In the case of SMEs, collaboration might be facilitated by bridging institutions such as entrepreneurial associations or even specialized research institutes (Chaminade, 2004).

Interactive learning might also take place when firms collaborate with the *knowledge creating and diffusing organizations* of the regional innovation system such as universities and research centres and other institutions like business services, entrepreneurial associations, etc., particularly for certain industries. Universities are often described as engines of growth, particularly at regional level. Yet despite the large amount of research on university–industry interactions (Mansfield, 1991, 1998; Meyer-Krahmer and Schmoch, 1998; Salter and Martin, 2001) the direct effects of the universities and research centres on the innovative performance of firms has proved difficult to trace (Fagerberg, 2004; Larsen and Salter, 2004). Universities play a double role as the providers of qualified human resources[13] (needed to build absorptive capacity) and as the providers of R&D. As R&D providers, universities and research centres are believed to be especially relevant for certain sectors (Pavitt, 1984) such as the pharmaceutical industry (Mansfield, 1995) or biotechnology (Asheim and Coenen, 2005), while appearing to be almost irrelevant for some others such as furniture (Klevorick et al., 1995; Larsen and Salter, 2004). As in any form of interactive learning the absence of absorptive capacity among the firms and other, organizations or limited generalized social capital might seriously hamper the collaboration between the different institutions.

2.3. Understanding the RIS in developing countries: an evolutionary perspective

Well-functioning RISs based on intense interactive learning are typically found in developed countries but seldom in the developing world. Despite a high degree of heterogeneity (different history, culture, political system) in the RIS of developing countries they nevertheless tend to be characterized by a low degree of institutional thickness and thus weak interactive learning (Amin and Thrift, 1995; D'Costa, 2006).

As opposed to dynamic clusters in the developed world that "are characterized both by dense local social interaction and knowledge circulation, as well as [by] strong inter-regional and international connections to outside knowledge sources and partners" (Gertler and Levitte, 2005: 487), clusters in developing countries are often simply local agglomerations of firms within the same industry without localised interactive learning (UNIDO, 2001), or 'casual' agglomerations with occasional horizontal linkages, limited cooperation and weak local institutions (Guerrieri and Pietrobelli, 2006), which in turn implies weak interactive learning.

The lack of local knowledge resources in the RIS in developing countries additionally forces indigenous firms to rely much more on TNCs as providers of knowledge and capital (Pietrobello and Rabellotti, 2007; Schmitz, 2006; Vang and Asheim, 2006). Thus for the indigenous SMEs, the users tend to be TNCs and the relationship between users and producers is normally highly asymmetrical in terms of power, knowledge and incentives to collaborate. SMEs in developing countries are often specialized in lower value-adding activities, which implies in most cases hierarchical or quasi-hierarchical relationships with the TNCs (Schmitz, 2006). Typically the TNCs are reluctant to engage in interactive learning with the indigenous firms due to their low absorptive capacity, the lack of differentiation between firms and the goods that they supply and the fear of losing knowledge (D'Costa, 2006), as the vast literature on direct and indirect spillovers from TNCs to indigenous firms has demonstrated (Dunning, 1993; Dunning and Narula, 2004; Lall and Narula, 2004; Narula and Marin, 2005).[14]

Good educational and research institutions are scarce, their administrative capacity limited, their competences usually meagre and their governance is often problematic. The consequence is that the quality of the knowledge providers might be far below what SMEs need to move from being low end to high-end providers of goods and services in the global networks.

Taking all the above into account, if we consider that an RIS exists only when all its systemic aspects are in place, it would be impossible to trace and identify any RIS in developing countries. Rather, the RIS in developing countries is better conceptualized in an evolutionary perspective. It should be understood as emerging where some of its building blocks are in place but where the interactions among its elements are still in formation and thus appear fragmented as Fig. 1 shows.[15]

In the emergent RIS we might expect that market transactions dominate the interactions between the build-

to their lead users (Infosys, for example, has 14 subsidiaries in different countries).

[12] The literature also emphasizes Marshall's 'atmosphere' or buzz (Storper and Venables, 2004) but as illustrated by Asheim et al. (2007) this is less important than initially claimed.

[13] In the cluster vocabulary this is referred to as specialized labour markets (Marshall, 1920; Storper, 1997).

[14] Nevertheless Schmitz's (2006) recent survey illustrates that the interaction between TNCs and indigenous firms can lead to upgrading for the indigenous firms. Schmitz points to that upgrading and innovation especially happens in relation to product and process improvements but only seldom for functional upgrading.

[15] We are aware of the limitations of these graphical representations of an innovation system. In this sense, the figure should be considered only as an illustration of the differences between the different phases of an RIS.

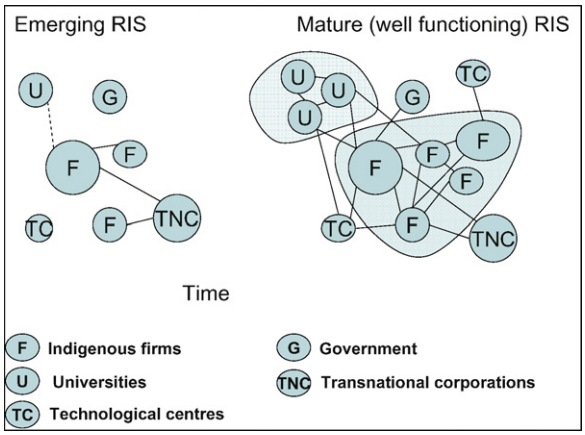

Fig. 1. Transition of the RIS.

ing blocks of the system (firms, universities and other knowledge providers and users). Additionally, emergent RIS frequently show weak inter-sectoral links, absence of interface units and universities specialized mainly in the supply of manpower (Galli and Teubal, 1997). In emergent RISs firms and other building blocks of the system are accumulating the competences and capabilities that are needed to engage in different forms of interactive learning. The emergent RIS might gradually evolve into a mature RIS. In the mature RIS interactions between the building blocks take place through market and non-market mechanisms such as informational links, interactions and other kinds of formal and informal networks. Firms and other organizations in the system have developed their absorptive capacity and are engaged in continuous interactive learning with other firms, users, universities and other organizations in the system. It follows that the university–industry linkages are strong and involve various forms of knowledge transfer (Galli and Teubal, 1997).

In this paper we refer to regional innovation systems in the first phase as *emerging RISs* and to systems in the second phase as *mature RISs*. We focus on the co-evolution between the upgrading strategy of the firms and the evolution of the RIS (this implies that there are numerous ways to move around the value chain yet also that they share certain characteristics). Considering that innovation is based on interactive learning and that this takes place in mature RISs, the firms' transition from pure cost-based competition to competing on the basis of knowledge provision needs to co-evolve with the move from an emerging RIS to a mature RIS. To understand how this transformation takes place we will analyse the emerging RIS in Bangalore, India. Special attention is paid to the different types of interactive learning, their emergence over time and the derived policy requirements. In particular the impact of the export-led growth model on the strength of local linkages, as a dimension not normally considered in the RIS literature on developing countries, is investigated. This is central for understanding the possibilities for upgrading, aiming at becoming specialised hubs in global value chains.

3. Evolution of Bangalore as a specialized hub in the provision of software services

Bangalore has emerged as one of the largest and fastest-growing software clusters outside the US (Nadvi, 1995; Parthasarathy, 2004a). It is not only a hub for software-related industries but also houses several high-tech clusters (e.g. defence, aeronautics) and is considered to be the scientific and engineering centre of India in terms of research and training and partly manufacturing. For pragmatic reasons Bangalore and Karnataka state is used almost interchangeably throughout the paper, though strictly speaking 'Bangalore' refers to the cluster of the IT industry and support organizations in and around Bangalore. Despite the weight of TNCs in the Bangalore IT sector, the large majority of firms are SMEs (NASSCOM, 2005).

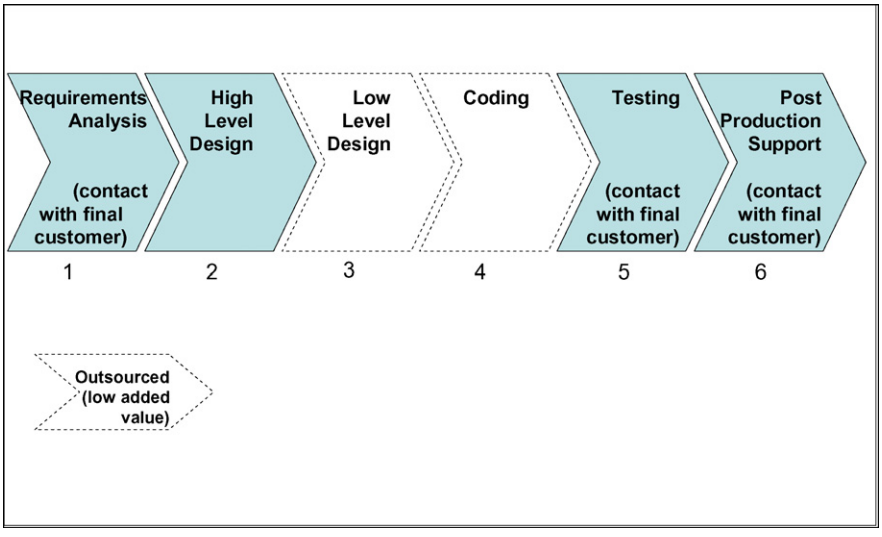

Fig. 2. A software development value chain. Source. Adapted from Arora et al. (1999).

India, and particularly Bangalore, has attracted the attention of scholars around the world for its impressive software growth export rates, superior to those of competing IT hubs such as Israel, Brazil or China (Arora and Gambardella, 2004; Athreye, 2005). The value of exports, for example, has typically grown more than 30% annually while revenues grow at rates of 30–40% (www.bangaloreit.in). The growth of the software industry in India is based on exports to global markets, mainly the US. This export-led development trajectory or model has important implications for the industrial structure of the RIS and the possibilities for upgrading the indigenous firms, as we will discuss later. India has an estimated share of 65% within the global IT services offshoring segment (NASSCOM-McKinsey Study, 2005).

However the majority of the exports are from low-end software services. The low value-added of those activities means that contact with the end-user is not necessary (Chaminade and Vang, 2006, 2008). Fig. 2 plots the software development value chain. The routine activities appearing in the middle of this chain basically draw on codified programming skills, while the sophisticated tasks draw on a combination of codified programming competencies and firm-specific – tacit and quasi-codified – capabilities related to the creation of customi developed through the creation of customized programs (Parthasarathy, 2004a).

Until recently Indian firms have been competing globally on the basis of the low cost of qualified human resources (e.g. mainly cheap engineers), the time-zone difference with the US (which allows the provision of round-the-clock tasks) and their English skills (Arora et al., 1999, 2001; Parthsarathy, 2004; Saxenian, 2001). However, this growth model is now in danger because of rising salaries in India and the emergence of competing countries such as China. The alternative for the indigenous firms seems to be to move to activities with higher added-value and start competing on the basis of innovation (D'Costa, 2006), as the pioneer example of the embedded software has shown (Parthasarathy and Aoyama, 2006). The question is how the system of innovation emerges and evolves to support this transition process and what the role of the regional government is in facilitating this transition. The development of Bangalore's innovation system will illustrate this transition process

3.1. The emergence of the RIS

As many authors have acknowledged (e.g. Arora and Gambardella, 2004; Athreye, 2005), the early development of Bangalore as a specialized hub in the software industry could be partly explained by the fact that some of the best educational institutions in India, such as the world renowned Indian Institute of Information Technology, the Indian Institute of Science, Raman Research Institute, National Institute of Mental Health and Neuro-Sciences, Central Food Technological Research Institute, Indian Space Research Organisation or the National Aeronautical Laboratory, were located there. The high concentration of knowledge providers in the region resulted in a critical mass of highly qualified yet cheap labour force which could explain the initial interest of the US firms in locating their outsourcing activities in the region.

The type of interaction between the indigenous firms and the TNCs has changed significantly over time. In the initial phase many SMEs specialized in the provision of low-end services, often based on body-shopping[16]—that is, sending software programmers to the (US) clients to provide maintenance services (Arora et al., 1999, 2001). Despite the criticisms that this strategy has received over time (see Parthasarathy, 2004b), it seems clear that it helped to reduce the institutional distance between the firms in the two countries. The indigenous firms became more familiar with the work organization and requirements of the US firms (delivery times, quality, reliability) while the US firms gradually started to outsource tasks to be performed entirely in Bangalore. Cooperation was facilitated by the role of the Indian transnational community in the US (Saxenian, 2001), particularly those that held important positions in US firms (Vang and Overby, 2006).[17]

As the Bangalore software RIS matured, both Bangalore and US firms improved their capabilities in managing outsourcing and offshoring, built up inter-cultural competencies and created their own local networks. Employee attrition and wage increases forced the firms to introduce advanced management techniques (Arora et al., 1999; Athreye, 2003). This, together with a tendency to codify procedures and improve the transfer of knowledge, has increased the organizational capital of some firms (hence their absorptive capacity) (Saxenian, 2001). The broader knowledge base combined with the good reputation as reliable suppliers in the US market plus an aggressive certification strategy among most Indian firms, have permitted some firms to move to the provision of R&D services for multinational firms. In some cases, some firms have even been able to develop their own innovation strategy and enter new niche markets with their own final products, as Fig. 3 shows (Parthasarathy and Aoyama, 2006).[18]

3.2. The transition to knowledge providers: caveats for the development of the RIS

Higher added-value activities involve the design and prototyping of new products or systems, which are consid-

[16] Bodyshopping was explicitly recognised in the Computer Policy of 1984 (Saxenian, 2001).

[17] Clearly the Indian community played a significant role in the establishment of subsidiaries in Bangalore of Motorola and Texas Instruments (Vang and Overby, 2006).

[18] It should be noted that what will be described next should be interpreted as an emerging trend rather than a consolidated tendency or general move in the cluster. It is however important to discuss the implications of such an emerging trend in the very early stages as policy makers could play a very significant role supporting this transition to higher added-value activities through innovation and interactive learning embedded in an effective regional system of innovation. To do so, we will take as an example the provision of R&D services in embedded software (Parthasarathy and Aoyama, 2006). Embedded software is a particular branch of the industry which combines hardware and software. It is designed to perform tasks without human intervention. Upgrading in this segment of the software industry is possible because the firms have acquired new capabilities, complied with international standards and gained international reputations while intensifying their local networks.

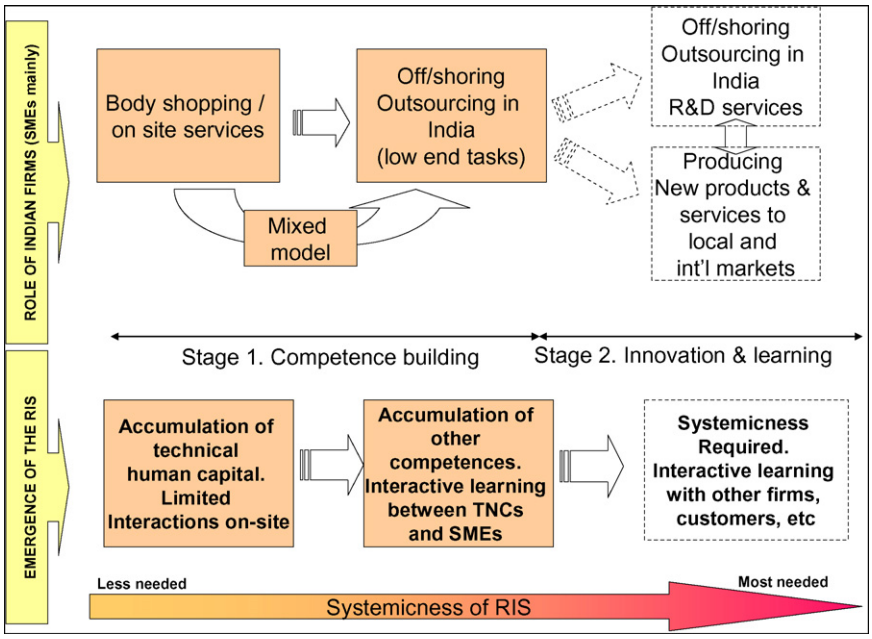

Fig. 3. Upgrading in Bangalore and the role of the RIS.

ered as R&D software services (Barr and Tessler, 1996; see Fig. 2, activities 1 and 2). According to the National Association of Software and Service Companies (NASSCOM), the main industry association, R&D service exports accounted for US$1.21 billion, or 15.8% of India's software exports, in 2001–2002. The figures grew to US$1.66 billion and 17.4% respectively in 2002–2003, and is estimated to grow to US$9.2 billion by 2010 (NASSCOM, 2005).

Offshoring or outsourcing R&D projects to India/Bangalore involves larger challenges than outsourcing/offshoring standardized and routine activities as in the past. The former activities are sequential, can be decomposed and codified. This is less the case for the R&D activities as markets for information, knowledge and technology (Arora et al., 2002) are riddled with imperfections derived from the culturally specific, embedded, complex, tacit and firm-specific knowledge associated with R&D activities. The outcome of an R&D service[19] is often a final product, almost ready to be commercialized (Barr and Tessler, 1996). However, IP rights for software are virtually non-existent in India apart from embedded software, which makes it highly risky to outsource or offshore innovative and/or R&D activities.

As acknowledged by the extensive literature on innovation systems, innovation activities require a well-functioning, mature RIS, based on interactive learning with users, other firms and knowledge providers. The question here is whether the emerging Bangalore RIS is evolving to a mature RIS that can provide the kind of support needed by the upgrading firms.

A closer look at the interaction between SMEs and TNCs documents that only a small group of firms has benefited from the interaction with the TNCs. As acknowledged by D'Costa (2006), "the top 20 Indian software exporters still account for about 60% of total exports, leaving more than 800 firms with the remaining 40% of the software market". Competition between those 800 firms is fierce, which translates into almost no cooperation among the indigenous SMEs (no generalized social capital and thus no interactive learning). Most of the SMEs located in Bangalore provide standardized services, therefore the incentives for the TNC to create long-term arrangements with the indigenous SMEs remain low. Their absorptive capacity also remains low. Only the small group of firms that has been able to build an absorptive capacity and create distinctive capabilities are benefiting from the interaction with TNCs. The growth model that the indigenous firms have adopted (i.e. export- and TNC-driven) has created a fragmented industry with very weak local linkages (D'Costa, 2006).

Apart from formal competencies developed by several Indian firms the high-end activities require interactive learning with the end-users (and often lead users); this requires developed technical capabilities and a deep knowledge on the business processes of the client (Arora et al., 1999). But those clients are mostly located in the OECD countries and therefore are not easy to reach by the Bangalore companies unless in collaboration with TNCs or with members of the trans-national community located in those OECD countries.[20] Local markets are also not well devel-

[19] Barr and Tessler (1996) consider R&D activities in the software industry as those directly related to the interaction of the final customer, that is, requirement analysis and high-level design. See Fig. 2.

[20] It should be mentioned here that most of the production of the software sector in India goes to external markets (according to Arora et al.,

oped and the tax system clearly disincentives firms to target the local market in favour of exports.

Undoubtedly, the co-location of a great number of educational and research institutions and high-tech clusters sets the grounds for the emergence of the RIS. However, if one eliminates the handful of world-class technical institutions, the picture is one of shortages of high quality staff (Arora and Badge, 2006; NASSCOM-McKinsey, 2005), and under-investment in research facilities. With few exceptions universities are almost exclusively devoted to the provision of (qualified) manpower to the local firms. Research is often more basic and, as a consequence, universities are not playing a significant role in supporting innovation and generating research results for the local firms. This explains why TNCs have increasingly started to build their own training centres in Bangalore as the recent examples of Infosys show. Interactive learning with universities is thus weak (D'Costa, 2006) although there have been some valuable results from the collaboration between universities and industry; for example, the collaboration between the Indian firm Encore and the Indian Institute of Science has led to a low-cost computer named Simputer.

The analysis of the emerging Bangalore RIS shows that none of the *systemic aspects* of the RIS is strong in the system yet. Interactive learning with other firms, with the final user or with the universities, is far from sufficiently developed. In this sense, there is a great opportunity for policy makers to put in place the conditions necessary for building Bangalore's future in collaboration with private firms.

4. Supporting the emergence and the transition of the RIS: regional innovation policies

Many authors have argued that the changing role in the global value chain of some Bangalore firms is the result of a deliberate strategy of the TNCs to locate in Bangalore and of the indigenous firms to build up their absorptive capacity; to a lesser extent it is seen as a consequence of policy interventions (Parthasarathy, 2004b; Van Dijk, 2003). While this might be true for regional policies, it might be debatable for national policies, particularly if one considers the initial role played by the central government in the location of high quality education and research institutions in Bangalore. The extensive, export-based model characteristic of the Bangalore software firms was only possible after the central government dismantled the rather counter-productive ISI strategy.[21] But with the exception of these two major policies and the provision of research institutes in the area (Parthasarathy and Aoyama, 2006), the role of the government in building the industrial and innovation capacity of the region has been very limited.

However, the move from an *emerging RIS* to a *mature RIS* that can support the transition of some firms from competing through low costs to competing through the provision of knowledge might require a much active role of the regional government, with the Bangalorian case being paradigmatic of systemic failures of problems (Chaminade and Edquist, 2006; Edquist and Chaminade, 2006) that call for policy intervention.[22] Systemic problems include, among others, the lack of capabilities of the firms, the lack of institutional framework or the existence of network problems derived from too weak or too strong linkages with other organizations in the system. This corresponds to the situation in the emerging Bangalore RIS, particularly with regard to the SMEs.

The regional government could pursue different initiatives to stimulate the development of systemic propensities in Bangalore's RIS, focusing specifically on the weak links in the system. What follows should not be considered as an exhaustive list of all possible instruments that the regional government might use to support the systemic propensities of the Bangalore RIS. Rather our intention is to illustrate with some examples that the regional government has an increasing role to play in the development of the RIS. A natural starting point would be policies aiming at *stimulating vertical and horizontal collaborations among indigenous SMEs*. This could be done by giving financial support (e.g. via R&D subsidies) only to consortia of SMEs or of SMEs and research institutions, or by supporting the creation of organizations that bring together local producers, researchers, service providers and even the government, with the objective of collectively solving a problem that is affecting the system. Additionally, very recently Bangalore has witnessed the emergence of a number of hybrid organizations that bring together research and educational institutions, government and local firms to discuss how to drive the regional growth through improving the *systemicness* of the RIS (D'Costa, 2006; NASSCOM-McKinsey, 2005). NASSCOM is also quite active in promoting the development of local entrepreneurial networks (Parthasarathy and Aoyama, 2006) and could play a coordinating role.

The regional government might play a role in stimulating the *collaboration between knowledge providers (e.g. universities) and SMEs*. This would require additional – and earmarked – resources for these activities, additional financial resources to knowledge providers and also a change of mindset among researchers who tend to favour collaboration with the large firms. It is important to increase the research capacity of the existing universities and research centres, leveraging the average quality of the centres and the number of researchers in the universities, though the focus should be on applied research. This is major hurdle as the incentives for the researchers to leave the university and create their own company (or be employed by a company) are high due to the larger salaries offered by the industry (Arora and Badge, 2006). In addition, attracting PhD students is a problem for the same reasons, thus constraining the potential future development of universities.

The strong dependency on TNCs of the indigenous SMEs and the limited *access to final customers* (e.g. lead

1999, exports account for 65% of the software revenue) and these numbers are growing.

[21] Though it should be remembered that Tata and other indigenous firms were established during the ISI phase.

[22] Chaminade and Edquist (2006) refer to problems instead of failures to indicate that there is no notion of optimality in systems of innovation, therefore one should not talk about systemic failures but systemic problems.

Table 1
The emergence of the Bangalore Regional Innovation System

	Stage 1. Competence building	Stage 2. Innovation and interactive learning
Content of work	Multinationals outsource specific tasks to the indigenous SMEs. TNCs are responsible for assembling the different modules into the final product. Competitiveness of the local SMEs is mainly based on costs	Indigenous firms start providing final products to specific market niches. In some cases, some cooperation between SMEs is needed to combine complementary competences. Indigenous firms start using their integration skills to integrate modules that are being developed in different firms
Local endowments of the RIS		
Human capital	In this first stage the focus is on the accumulation of technical human capital. Bangalore provides enough technical human capital. There are good technical schools located in the area although the managerial skills that are needed for the transformation are lacking	In this second stage new skills are needed beyond technical skills. Indigenous firms need to be able to integrate the different modules into the final product
Social capital and networks	The main linkages are those established between the TNC and the local indigenous SME. Few SMEs collaborate with other SMEs. Social capital seems not to be relevant in this first stage	Social capital starts to play a crucial role stimulating and supporting interactive learning between the indigenous SMEs. In the Bangalore case, a new set of horizontal relationships seems to be emerging, both formal and informal (particularly in embedded software)
International links		
Transnational corporations	The focus in this first phase is to attract transnational corporations. In this first phase TNCs play a significant role in the RIS, as they link the indigenous SMEs with the international markets. They may also transfer some competences to the local SMEs as well as (and mainly) stimulating the introduction of standards (acquisition of organizational competences) in the local SMEs	SMEs and TNCs could collaborate in the provision of R&D services (traded externalities leading to spillovers) and offshore R&D labs (untraded spillovers)
Transnational communities	Transnational communities are also crucial in this first stage. They contribute to the development of the RIS and the indigenous SMEs by reducing institutional distance which in turn reduces transaction costs	The role of transnational communities in this phase has not yet been studied. However, we expect them to continue to be relevant as they reduce the institutional distance and facilitate the direct access of indigenous firms to the final markets

users), and the contrasting experiences in Ireland, Israel and China (Breznitz, 2005; Sands, 2005; Tschang and Xue, 2005), suggest that the government could play an important role by using public procurement as an instrument to stimulate experimentation and innovation in the local firms (i.e. the government as a lead customer) (Arora and Gambardella, 2004, 2005). This has been done in India on a very limited scale (Kumar and Joseph, 2006). Public procurement might be very important to create local markets and give the right incentives to the indigenous SMEs to use their capabilities for innovation.[23] However, public procurement might also steer the local innovation towards products or services that have relatively low value in international markets. In this sense, a well-informed government is a prerequisite for the success of public procurement. The public procurement should explicitly build on the areas of potential specialization advantages that are within Bangalore's reach. One crucial pillar in this specialization strategy is Bangalore's unique ability to be competitive in services that combine low-cost, labour-intensive activities and high-end activities, especially those that require face-to-face collaboration between the high- and low-end activities. Additionally, there is a need for developing policy measures and evaluating tools that take into account the position of the RIS in global competition. Policies could focus, for example, on competency specialization, on the match between competition, coordination and interactive learning, and on the structure of networks.

5. Policy implications

From a policy perspective, one of the clearest conclusions is that the role of the regional and central government changes over time (and should do so in parallel with the transformation of the strategies of the firms and the RIS). Table 1 summarises the main findings of the case.

In the initial phase of the *emergence* of the RIS the regional government bodies do not play an important role as the factors for attracting TNCs usually fall within the domain of the central government, apart from ensuring a well-functioning infrastructure and bureaucracy (i.e. limited corruption and red tape). The countries compete via the traditional measures associated with comparative

[23] Many scholars argue that Indian SMEs have already the design capabilities.

advantages in developing countries, i.e. low costs, the ability to attract standard and routine activities, and so forth. The central state however should ensure sound macroeconomic policies, non-discrimination of exports and imports, and possibly selective measure protecting infant industries. Central state policies can focus on the supply side,[24] on reducing the transaction costs for TNCs to outsource or offshore,[25] among other issues. The latter can be done mainly by reinforcing the national and regional institutions (regulations, IP and other patent laws, etc.) or training the indigenous firms in the management of inter-cultural differences and possibly targeting members of the transnational community. The Bangalore case also suggests that national and regional governments can play a significant role in supporting the emergence of high-quality educational and research institutions in the region.

The role of the regional government becomes more prominent during the second phase when a well-functioning (i.e. more mature) RIS is needed. Then a sound knowledge of the different actors in the system, their capabilities and their interaction is needed, especially for policies targeting SMEs. The regional governments ought to stimulate the construction of local networks and eventually even the local markets through public procurement. This calls for a decentralized territorial decision-making structure as regional governments – given the developed competencies and capacities – possess the local stock of knowledge, especially on 'emerging' needs. In other words, regional governments are likely to play a more conducive role in facilitating the upgrading process as they have the incentive of being dedicated to the needs of their particular region (though even a region like Karnataka has it own 'twisted' incentives – i.e. conflicts between urban and rural areas – that lead to occasional discrimination against the software industry). National government bodies might have competing development agendas (growth versus regional equality, for example) and thus be not equally dedicated to one particular region's needs. Additionally, if regional government bodies are directly involved in setting up and managing education and research institutions they are better able to tailor it to the specific needs of the firms and organizations in the region. And the regional government bodies will probably be more sensitive to the SMEs' particular needs in this context. However, it is crucial that the regional government bodies collaborate with the central government bodies to support the global positioning of the RIS.

6. Conclusions

While the study cannot be generalized it nevertheless provides suggestions that the RIS 'policy template' needs to be modified and more sensitivity to evolutionary aspects should be emphasised[26] and that these aspects need to be understood in a global-local context. On a general level market-based development strategies in the initial phase might prove more efficient than assumed by RIS theorists and thus there might be less need for regional innovation policies as such (apart from some indirect policies stressing the supply side). Devolution is also less required than assumed by the RIS literature, though the systemic propensities need to be emphasized, in the sense that RIS policies without a complementary macro-policy will not result in regional development. In addition there seems to be less need for emphasising policies underpinning social capital formation and interactive learning in the initial phase; interactive learning starts to be relevant when the indigenous firms have built capabilities up to a certain level (before this there will be diminishing return to collaboration with other indigenous firms as opposed to TNCs). In other words, markets have at least in this case proven to be adequate for stimulating the appropriate specialization in global competition.

However, in the second phase reliance on markets seems less convincing as the market imperfections constrain distance-based collaborations – in addition the incentives for distance collaboration are smaller as cost differences are minor. Thus while there is a need for upgrading the human capital (maintaining a focus on the supply side), the government public procurement policies can become central for compensating for market imperfections and lack of localised lead customers, and for stimulating interactive learning. The policies should emphasise and redevelop the areas within which the regions hold specialisation advantages in global competition. A decentralized territorial decision-making structure becomes crucial in the latter phase but contrary to what is normally suggested by RIS policies, collaboration with central government is crucial for gathering the information needed for designing and evaluating the policy measures to support the global positioning.

The case illustrates the dynamic nature of the regional innovation system. It highlights the need to adopt a flexible and accommodative policy that takes into account the changes in the needs of the indigenous firms, the endowments of the regional innovation system and the international networks, and places them in a dynamic global context. As Saxenian (2001) suggests, upgrading requires moving away from 'replication' of successful models (like Silicon Valley) to new pathways that respond to the specific conditions of each region and its potential to become a specialized hub in global value chains. The RIS approach allows policy makers to identify the systemic problems of the RIS where policy interventions are most urgently needed. We argue that, unless there is a clear investment in the systemic propensities of the RIS, the possibilities for the indigenous SMEs to upgrade are seriously limited. The suggested policy measures and tools are to be considered illustrative only, as it is beyond the scope of the paper to include all possibilities. However, having said

[24] In contexts where education is within the domain of the regions this changes the division of labour between the central state and the regions.

[25] We do not suggest that there is only one way to achieve growth in the initial phase, and research analysing the contrasting experiences of the home-market centred experiences of China and Brazil is called for (Arora and Gambardella, 2004).

[26] For a discussion of how to make regional policy sensitive to industrial differences, see Chaminade and Vang (2006, 2008).

this there is also an urgent need for additional research on innovation policy in developing countries – and the developed world too – on designing, measuring/evaluating and implementing policies that bring together local or regional dynamics with global positioning analyses.

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