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Scaling Innovation in Southeast Asia: Empirical Evidence from Singapore, Penang (Malaysia), and Bangkok

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Scaling Innovation in Southeast Asia: Empirical Evidence from Singapore, Penang (Malaysia) and Bangkok[1]

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Abstract

Our survey of 1,600 manufacturing firms in Singapore, Penang, and Bangkok shows that the breadth and efficiency of innovative activities still lag considerably behind those found in eleven European regions. Co-operations are virtually indispensable for corporate innovation processes in the region. Their strong orientation towards headquarters or R&D centres of multinational corporations and lead users in technologically advanced countries yields a discontinuous territorial pattern of linkages in which firms 'leapfrog' neighbouring ASEAN countries, contrasting sharply with the distance-decay pattern found in Europe. Further research should employ multi-dimensional concepts of space to accommodate the territorial, techno-economic, organisational, relational and temporal dimensions of innovation networks.

In the past three decades the Newly Industrialized Economies (NIEs) of Southeast Asia have undertaken a historically unique economic catching-up process vis-à-vis the established industrialized countries. Between 1971 and 1996, the real gross national product in most countries of this growth region increased at average annual rates of between six and ten percent. After the Asian crisis of 1997/98 most of the emerging economies in the region initially returned rapidly to the path of growth. However, doubts remain about the sustainability of the "Asian Miracle" (THE WORLD BANK, 1993), which KRUGMAN (1994) called a myth due to the small contribution of technical progress demonstrated in growth accounting studies.

Although technological change is considered to be one of the decisive determinants for judging the future economic perspectives of the Southeast Asian NIEs, so far no representative empirical surveys are available on the patterns and scales of innovation and co-operation activities at the micro level in Southeast Asia. While econometric studies are encumbered with a series of problems concerning their methods and content, case studies alone can, at best, provide anecdotal evidence. Some Southeast Asian governments carry out periodical surveys of research and development (R&D) activities, for instance in Singapore since 1978 (annually since 1990, most recently A*STAR, 2004), or biannually in Malaysia since 1992 (most recently MASTIC, 2004). However, R&D surveys capture little more than the tip of the iceberg of innovation activities, especially in the context of NIEs. As WONG (1995) stresses, the generation of technical knowledge by means of R&D is of less importance in NIEs than in industrialized countries; in contrast, the diffusion of imported knowledge by means of adoption and adaptation is of greater relevance. Thus innovation surveys need to go beyond formal R&D activities in these countries, a necessity acknowledged by MASTIC's first National Surveys of Innovation undertaken in Malaysia (MASTIC, 2001, 2003).

To sustain a high level of income and employment in the increasingly international and knowledge-

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based competition between locations, spatial economic systems at different scales (locations, regions, countries, and supranational blocks) must continually produce or apply new knowledge, as is represented, above all, by technological product and process (TPP) innovations. To allow for internationally comparable measurement, the OECD's Oslo Manual defines TPP innovations as comprising implemented technologically new products and processes and significant technological improvements in products and processes (OECD, 1997).

The extent to which a region succeeds in generating a continuous stream of TPP innovations depends primarily on its endowment with innovation actors (agents), and especially with innovating manufacturing firms, knowledge-intensive business services (KIBS), as well as research institutions. Like Hayek's seminal "division of knowledge", interactive models of innovation imply that a region's innovative capabilities are, in addition, decisively influenced by the interaction of the innovation actors and by their more general environment. This point is taken up by the concepts of territorial (national, regional) innovation systems. Since new knowledge is initially still incompletely codified or *tacit*, its exchange is favoured by the territorial proximity of the innovation actors which enables face-to-face contacts. This aspect provides a critical foundation of innovation research in contemporary economic geography, where it is reflected empirically in spillover research, or theoretically in the concepts of regional innovation systems and the related family of territorial innovation models (MOULAERT and SEKIA, 2003).

While research on corporate innovation activities in Southeast Asia has started to move beyond the dismal concept of total factor productivity growth, representative studies on the prevalence and scales of innovation networks still focus exclusively on the advanced industrialized countries. It is our ambition, therefore, to build on the experience gathered by the European Regional Innovation Survey (ERIS) in eleven sub-national regions across Europe to measure, evaluate and compare

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innovation activities, and most importantly to scale innovation networks in the survey regions of Singapore, Penang (Malaysia) and Bangkok[2]. In the systems of innovation literature and under the TPP innovation paradigm, manufacturing firms are traditionally seen as the core actors within a NSI as producers and users of technological knowledge. Our empirical results will therefore be based on postal surveys of a total of 1,585 manufacturing establishments.

When transferring concepts such as "innovation" and "networks" to Southeast Asia, the following aspects have to be taken into account:

1. Catching-up: Late industrialization offers NIEs the possibility of making use of the most recent technologies available in the industrialized countries, thus missing out older stages of technological development. Technological leapfrogging as modelled by BREZIS, KRUGMAN and TSIDDON (1993) may be aided by the microelectronics revolution, as a number of authors suggested in the 1980s (PEREZ, 1985; SOETE, 1985). However, this leapfrogging argument stands in contrast to the path-dependent and cumulative nature of economic and technical development advocated by evolutionary economics (DOSI, 1988). This latter view, which has gained prevalence from the 1990s onwards, stresses the importance of absorptive capacity to develop technological capabilities, both at the level of the firm (COHEN and LEVINTHAL, 1990), and for entire societies (DAHLMAN and NELSON, 1995).

2. The dominance of multinational corporations (MNCs): Given suitable absorption capacities, the strong presence of MNCs can provide Southeast Asian NIEs with access to technical knowledge available world-wide. On the other hand, the internalized mode of technology transfer offered by MNCs is frequently viewed as stifling the development of endogenous technological capabilities. This becomes strikingly obvious when compared with alternative models of capacity building, such as those employed by Taiwan and South Korea which have

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so far developed a much deeper technological basis through externalized modes of technology transfer based on networks of SMEs and public research institutions and the nurturing of vertically integrated *chaebols* with large-scale corporate R&D, respectively (cf. LALL, 2001; WONG, 1999).

3. Cultural determinants: The cultural environment must also be considered as an important factor influencing the innovation and co-operation behaviour within the framework of an innovation system. Relevant concepts for Southeast Asia include *guanxi* networks, "a form of social exchange based on sentiments and emotions and [...] marked by a mutual belief in reciprocity" (CHAN, 2000) as well as a particular fear of losing face which occasionally translates into fierce competitive behaviour, denoted by the Hokkien term *kiasu*. However, besides the overseas Chinese one (YEN and YAN, 2002), Malayan and Indian business cultures also need to be considered to account for the ethnic and cultural diversity of Southeast Asia.

Our empirical research is theoretically founded in the systems nature of innovation and the resulting territorial and non-territorial scales. Being subject to a topical debate in the geography of innovation, the relation and interaction of scales will be discussed in the second part of the paper as well as the transferability of “Western” concepts to Asia. Following a brief introduction to our research methodology, the results from three thematic focal points of the survey are to be discussed in more detail in the fourth section: the innovation capabilities of the manufacturing firms in the survey regions, their propensity to co-operate with external partners in the innovation process, as well as the scales of these co-operation linkages. Finally, we summarize our results and derive unsolved research questions.

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Systems, Scales and Spaces of Innovation

Our understanding of technological change has evolved from the linear model of innovation as a 'bucket brigade' from invention to market introduction to diffusion to non-linear, interactive models such as the influential "chain-linked model of innovation" conceived by KLINE and ROSENBERG (1986). Besides feedback loops at all stages of the process, the chain-linked model stresses the importance of interactions with external partners to tap the "distributed knowledge base" (SMITH, 2000) reminiscent of HAYEK'S seminal principle of the division of knowledge (HAYEK, 1937, 1945). Interactions can therefore be regarded as the link between innovation and space. From a geographic viewpoint, the prime merit of interactive models of innovation is that they stress the systematic character of innovation, thus laying the conceptual base for concepts of territorial and non-territorial systems of innovation.

Generally speaking, a system of innovation comprises all actors, organizations and institutions whose actions and interactions influence innovation processes or set the framework for the intensity and direction of technological change (HALL, 1994). Like all systems, systems of innovation thus consist of elements and networks of interaction between them. Across all territorial and non-territorial scales discussed below, innovation systems can be generalized to mainly include the following organizations, or "players" in the words of NORTH (1994b): firms mainly in manufacturing industries[3], knowledge-intensive business services (KIBS), organizations of knowledge production and diffusion such as universities, polytechnics and publicly funded research institutions, the wider education system, bridging organisations like transfer agencies, science parks and business incubators, but also financial institutions such as banks and venture capitalists, and further organisations responsible for the formulation and implementation of policies affecting innovation and the setting of standards.

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If these are the "players", then their actions and interactions are subject to a set of constraints or "rules of the game" (NORTH, 1994b), such as constitutions, laws, incentives, technical standards, cultural norms, values, conventions and the like. The performance of an innovation system depends crucially on the extent to which the different actors network with each other and aim at joint solutions. This requires an inclination for co-operation, which is in turn dependent on a joint basis of trust. The socio-cultural environment can produce institutional arrangements which can lead to routine-like behavioural patterns and to a reduction of transaction costs in the face of technological as well as market uncertainties (for a recent overview see WILLIAMSON, 2005).

Systems of innovation can be delineated according to territorial or technological criteria. Studies on the geography of innovation naturally focus on territorial systems at various scales, i.e. global, supranational or continental, but most frequently at the national, regional or local level (cf. EDQUIST, 1999). However, we are going to show that due to the shortcomings of territorial innovation models, non-territorial systems and spaces of innovation should also be taken into account.

Despite the simultaneous forces of globalization and localization, the generation and diffusion is still significantly shaped by institutional and cultural forces at the national level (FREEMAN, 1995). Independently but almost concurrently developed by FREEMAN (1987), LUNDVALL (1992), and NELSON and ROSENBERG (1993), the concept of *national systems of innovation (NSI)* has successively evolved from a system of knowledge production through R&D into a system of innovation and learning in which the generation of technological knowledge is linked to the economically relevant aspects of knowledge diffusion, transfer and application (GALLI and TEUBAL, 1997; LUNDVALL et al., 2002).

Resonating visions of the "end of the nation state" and the simultaneous "rise of regional economies" (OHMAE, 1995), the notion of *regional systems of innovation (RSI)* transfers the characteris-

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tics of an NSI to the subnational scale (COOKE, 1992, 2004, DOLOREAUX 2004). Its core assumption is that innovation activities are significantly influenced by specific regional networks and environments. Despite its origin, an RSI is more than a scaled-down version of an NSI (AUTIO, 1998, HOWELLS, 1999) since the regional scenery can deviate from the national setting in a number of ways, such as a region's industrial structure, educational infrastructure, scientific and technological capabilities or its capacity to absorb knowledge from outside the region (ARCHIBUGI and MICHI, 1997). Both organizations and institutions can be limited in their territorial outreach. For instance, territorial innovation models such as industrial districts, innovative milieus or learning regions stress the importance of a common cultural basis creating trust, thus reducing transaction costs and uncertainty whilst allowing for collective learning.

The RSI concept can be credited for highlighting the systemic nature of regional innovation activities and the relevance of the subnational scale for innovation processes organized on superordinate territorial scales. However, both the RSI concept and the entire family of "territorial innovation models" assembled by MOULAERT and SEKIA (2003) tend to pay unduly little attention to system openness and integration in national and international networks. Eventually, no RSI can exist in isolation from sectoral and/or territorial innovation systems at higher territorial scales, for which they fulfil specific functions (BRESCHI and MALERBA, 1997; HOWELLS, 1999).

Territorial Innovation Systems - A Suitable Concept for Newly Industrialized Economies?

Critiques of territorial innovation systems tend to focus on the appropriate scale, such as the continuing relevance or not of the national scale in the face of globalization and localization. However, in the context of our paper, we would like to focus on aspects concerning the applicability of these concepts to our study regions in Southeast Asia. Our main concern here is that concepts of

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territorial innovation systems have been derived from successful examples situated in leading industrialized economies, such as the RSI concept initially and still overwhelmingly focusing on a limited number of textbook case studies such as Silicon Valley, Route 128, the Third Italy, Baden-Württemberg and the like. Although the ongoing debate has produced some more representative accounts (most notably COOKE et al. 2004), it is still far from clear to what extent it can be meaningfully applied to the 'grey mass' of regions that do not fit into the stylized dichotomy of the 'bad' and the 'beautiful' (BOSCHMA 2004, p. 1012). In advanced countries, let alone to NIEs. It appears widely accepted now that concepts of territorial innovation systems need to be modified in a number of ways to suit the context of NIEs in Southeast Asia (cf. VIOTTI, 2002), of which we wish to highlight five:

– Technology development vs. deployment: While advanced industrialized countries generate a substantial amount of new technical knowledge, NIEs rely first and foremost on access to technologies produced elsewhere. Hence, their technological capabilities are geared towards the absorption, adaptation and application of knowledge rather than to the production of new knowledge (WONG, 1995, 2001; Lall, 2000). While such aspects of adaptation and diffusion were neglected in the earlier NSI literature, they do assume more prominence in more recent variations, such as the Aalborg Version of an NSI (LUNDVALL, 1992), or the territorial innovation model of the 'learning region' and relating models of institutional learning that form one of the underlying concepts of an RSI (FLORIDA, 1995; COOKE, 2004). However, none of these models has been properly calibrated and empirically tested to suit the specific demands of NIEs so far. Territorial systems of economic learning on the national or subnational scale might be a useful attempt to improve on previous efforts. By focusing on the management of technology diffusion, they shift the focus from radical innovation based on endogenous re-

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sources to incremental change along established trajectories based on external knowledge (MATHEWS, 2001; VIOTTI, 2002).

– Systems of innovation as an *ex ante*-concept: Developed inductively by studying advanced economies, territorial systems of innovation are essentially an *ex-post* concept to describe, analyze and compare highly developed systems with strong institutional and infrastructural bases. In contrast, developing countries are commonly characterized by a much less homogenous economic structure (often dual economies), a weak base of suppliers and service providers, a limited pool of knowledge and instable institutions hindering efficient learning processes. It is here that LALL (2000) sees an important case of market failure demanding selective and temporary policy intervention to maximize the benefits of international technology spillovers. As a consequence of their relatively short history of industrial development, systems of innovation in NIEs should rather be regarded as an ex-ante model and a guide for economic and technological development (AROCENA and SUTZ, 2000). Hence, studies on innovation systems in the developing world should focus on the construction and promotion of such systems (LUNDVALL et al., 2002).

– Integrating the international dimension: Given NIEs' reliance on technology imports and their relative lack of critical systems elements, it is necessary to highlight the role of international linkages and alternative modes of technology transfer as a vehicle for the development of emerging systems of innovation (WONG, 1995, 2001). Due to a dualistic and inhomogeneous economic structure and a weak domestic knowledge base, interactions between national agents are seen as less important in emerging than in advanced countries (WONG 2001, ERNST 2002). Furthermore, the modernisation and development of the economy is to a much larger extent driven by MNCs than in industrialised countries (FROMHOLD-EISEBITH

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2001). Consequently, ERNST (2002) demands that "international linkages need to prepare the way for the development of national innovation systems". Especially the RSI concept and its related territorial innovation models until recently had little to say about the relevance of interregional interactions. Although this has changed in more recent writings, the modification of the industrial districts approach by PARK and MARKUSEN (1995, also MARKUSEN, 1996) still stands out: while (Neo-)Marshallian industrial districts are rooted in flexible specialization, new industrial districts in late industrializing countries are still linked to Fordist structures of mass production. Hence they are predominantly embedded in non-local networks, at least initially when starting off as satellite or hub-and-spoke industrial districts. ASHEIM and VANG (2004) follow a similar path when extending the RSI concept to include external capital, transnational knowledge sources and MNCs. Taking these modifications into account, they stress the importance of developing firm and regional absorptive capacity, the necessity to embed MNCs locally, and regional policies to concentrate scarce resources for the promotion of industry clusters. In a similar fashion, the typology developed by Cooke (2004) also caters for the vast variety of RSI that can be found worldwide.

– Glocalization of innovation as an opportunity for NIEs: As most economic activity, innovation is subject to the countervailing forces of globalization and localization. The globalization of innovation comes in three dimensions: the increasingly global exploitation of technology through exports, licensing, patenting or overseas production, the increase of technological collaboration, and the increasingly global generation of technology through the internationalization of R&D by MNCs (ARCHIBUGI and MICHIE, 1995). However, the latter lags considerably behind the internationalization of other corporate functions such as investment, sourcing, production or distribution (KOOPMANN and MÜNNICH, 1999). In their study of the

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US patenting activities of the world's largest manufacturing firms in the late 1980s, PATEL and PAVITT (1991) still stated "an important case of non-globalization". It was only about that time that technologically advanced MNCs began to split up their innovation processes territorially and recombine them flexibly in response to changes in technology and demand (DUNNING, 1994; Pearce, 1997; FLORIDA, 1997; CANTWELL and JANNE, 1999). This led not only to the rise of *technology sourcing* as a new motif of foreign direct investment (CHESNAIS, 1988), but at the same time offers new opportunities for developing countries to access state-of-the-art technical know-how. However, the scope of NIEs to benefit from the globalization of technology production is limited, since MNCs tend to locate their overseas R&D units in the lead markets of North America, Europe and Japan. It therefore seems more appropriate to speak of "triadization" rather than true globalization of innovation (IAMMARINO and MICHIE, 1998; HOWELLS and MICHIE, 1998; RUGMAN, 2000). At the sub-national scale, MNCs choose regional centres of competence as locations for their R&D units to benefit from localized knowledge spillovers, in many cases as 'listening posts' to absorb new trends in technology and demand (CANTWELL, 1999; REGER, 1998). This implies that NIEs need to develop a critical mass of internationally reputed scientific and technological competence in selected niches of technology. Otherwise, developing countries and lagging regions risk further marginalization in technological and hence in wider economic terms (CANTWELL and IAMMARINO, 2000). In any case, LUNDVALL et al. (2002, p. 226) demand that the relationships between globalization and national/local systems should be further researched: "It is important to know more about how globalization processes affect the possibilities to build systems of innovation in developing countries".

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– Many Asian countries differ strongly from advanced economies in terms of political governance (FROMHOLD-EISEBITH 2001). Generic features distinguishing many Southeast Asian NIEs from industrialised countries in the western world include inefficient or even corrupt bureaucracy, particular strategies for late industrialisation such as import substitution vs. export promotion, the policies towards education and S&T, the special role of state-owned companies and the institutional framework for regional policy (FROMHOLD-EISEBITH 2001, BERGER 2005). However, these generalizations tend to disguise the region's institutional diversity. As shown in a recent overview (JOMO, 2004), several Southeast Asian NIEs can be classified as 'development states' characterised by a high degree of centralised political power, with government intervening in many spheres to pursue the prime goal of economic development. This model is most pronounced in Singapore, the archetypal developmental state (CASTELLS 1988, HUFF 1995, LOW 2002). On the other hand, Thailand currently represents a model of a country run by strong, 'CEO-style' politicians (THE ECONOMIST 2004). Policies are often implemented in a sense of purposeful strategic management for catching up, fostering enhanced learning (GU 1999). For Malaysia, GOMEZ and JOMO (1999) employ the concepts of rent and rent-seeking as tools to study how political patronage influences the accumulation and concentration of wealth.

To conclude our critique, the main common weakness of all territorial systems and related models of innovation is that they assume a unilateral causal link between territory and technology. It is here that non-territorial concepts of innovation systems can add new momentum to the geography of innovation.

Technology versus Territory

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Non-territorial systems of innovation include all attempts to delineate systems of innovation based on technological or industry criteria; their territorial dimension arises as a complementary effect only, if at all. CARLSSON and STANKIEWICZ (1991) define a technological system as a network of vertically and horizontally linked actors and organizations interacting in a specific industry with a specific infrastructure to generate, diffuse and apply technological knowledge. In this perspective, technological systems comprise three elements: 1. the economic competence of firms which is shaped by learning, bounded rationality, as well as the national and regional environment; 2. strong reciprocal externalities resulting from the networking of producers, customers and competitors; 3. organizations and institutions including the educational system, bridging and financial institutions, associations and the degree of internationalization of the industry in question (CARLSSON and JACOBSSON, 1997).

BRESCHI and MALERBA (1997, p. 131) choose a different approach by defining a sectoral innovation system (SIS) as all firms participating in an industry's innovation activities by manufacturing products, or by developing or using the respective technology. These firms are systematically linked by interaction and cooperation in the generation of new technology, as well as by competition on the market. In contrast to CARLSSON and STANKIEWICZ, BRESCHI and MALERBA focus on firms as the central actors and the importance of competitive dynamics and the market environment in the process of innovation. Other actors and organisations play an indirect role by affecting corporate innovation activities and by setting rules of competition. Quite differently from territorial systems of innovation discussed above, BRESCHI and MALERBA explain the territorial extent of their SIS endogenously as a result of the technological regime (DOSI, 1982). A regime is characterized by technological properties, such as the opportunities and conditions for appropriating technology, the degree of cumulativeness, the kinds of knowledge involved (e.g. tacit vs. codi-

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fied), and the mode of transfer and communication. Since SIS are organizationally and institutionally embedded, in this view a territory does not define a system of innovation, but rather fulfils specific functions in various SIS. STORPER (1996) even takes this explanatory pattern one step further by suggesting product-based innovation systems as the appropriate level for analysis and policy-making.

From a spatial science perspective, it is quite unsatisfactory that SIS do not provide a proper means to delineate systems of innovation in territorial space. The concept treats the territorial embeddedness of technological trajectories only vaguely and largely neglects the institutional infrastructure that is inseparable from a specific territorial scale, i.e. national or regional. Although concepts of non-territorial systems of innovation usefully complement those of territorial systems of innovation, they alone are insufficient to replace them.

Concrete examples illustrate the overlap between territorial and non-territorial innovation systems in practice, i.e. innovation processes do not only cut across various territorial scales (local, regional, national) as advocated by BUNNELL and COE (2002), but also involve non-territorial or sectoral systems of innovation at the same time. For instance, Singapore's semiconductor industry is integrated in the city state's national innovation system as well as in the industry's wider regional and global production networks. OINAS and MALECKI (1999) capture this multi-scalar nature of innovation in their functional concept of spatial innovation systems which consist of "overlapping and interlinked national, regional and sectoral systems of innovation which all are manifested in different configurations in space" (p. 10). However, the relative importance of technological versus territorial factors in explaining technological capabilities largely remains uncharted territory, as do the interactions between technology and geographic space (JOHNSON, 1997). To make matters even worse, technology and territory form only two – albeit presumably

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not insignificant – dimensions of innovation space. Hence, multi-dimensional concepts of space are needed to capture collaborative innovation processes, of which territorial space is just one dimension.

Towards a multi-dimensional concept of innovation space

Geographical proximity between innovation actors can foster their interaction, thus facilitating the exchange of tacit knowledge. However, the relevance of geographical proximity for interactive innovation processes tends to vary between industries (BRESCHI, 1999) and by the maturity of the innovation process itself, depending on the ratio between codified and non-codified knowledge employed. Industry differences are usually explained by technological parameters (LUNDVALL, 1988): If the technology is sufficiently stable and standardized, knowledge can be transferred across any distance at low cost. As long as the technology is highly complex and still subject to frequent changes, geographical proximity can improve the innovative performance of the actors involved. Hence, geographical proximity is most important in times of radical change, or during shifts from one technological paradigm to another (DOSI, 1982). During such a period of uncertainty, face-to-face contacts can assume paramount importance for the exchange of non-codified knowledge – a mechanism which explains the highly localized nature of new basic technologies, such as microelectronics in Silicon Valley (SAXENIAN, 1994). While this argument is about technological *systems*, the relevance of geographical proximity tends to decline in the course of a *product's* development process. During the early stages of the innovation cycle, tacit knowledge and learning by interacting demand frequent face-to-face contacts, before the successive codification of knowledge reduces the need for interaction, while at the same time allowing the use of other means of communication (cf. RALLET and TORRE, 1998).

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Consciously or not, scholars of the geography of innovation tend to overestimate the relevance of geographical space in collaborative innovation processes (RALLET and TORRE 1998; GERTLER, 2001). Eventually, OINAS and MALECKI (2002) conclude that "there is the possibility that neither most nor the key relationships are necessarily proximate." Depending on the industry and region under study, empirical research into the relationship between geographical proximity and collaborative innovation yield very different results, altogether far from supporting a clear causal link. It therefore seems inevitable not just to investigate the cross-scalar territorial nature of innovation as advocated by BUNNELL and COE (2002), but also to take non-territorial dimensions of space into account. The combination of territorial and non-territorial dimensions leads to a multi-dimensional space in which interactive innovation processes can be mapped. SIERRA (1997) distinguishes the following interdependent non-territorial dimensions of space[4]:

– **Techno-economic space**: To engage in collaborative innovation, actors must belong to the same field of technology, or to related fields at least. However, these fields of technology are not equivalent to product or industry classifications used in official statistics. To overcome this problem of concordance (GRUPP, 1998), they need to be matched using lists of corresponding products, industries and fields of technology. Analogously, LUNDVALL (1992) suggests measuring the distance between actors in an “economic space” using input-output coefficients. He thus revives a concept of space previously advocated by PERROUX (1955), whose concept of growth poles also rested on an abstract kind of “economic space”, a system of functional relations with no direct link to their territorial dimension, or “genomic space” in the words of PERROUX (1950).

– **Organizational space**: Following NORTH (1994a), organizations co-ordinate the action of their individual members by a set of specific rules, norms and routines such as a common

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language or repository of knowledge. Collective beliefs such as 'corporate cultures' lead to a convergence of individual behaviour (RALLET and TORRE, 1998). Interactive learning between organizations thus requires actors first to develop common codes which help reduce the organizational distance between them (LUNDVALL, 1993).

– The related concepts of **relational**, **cultural** and **social space** capture non-economic relations between individuals based on similar attributes such as age, profession, language, mutual sympathy and the like, values such as work ethics, behavioural norms or shared opinions, a common cultural basis as well as mutual trust. These features determine the social cohesion between innovation actors, thus directly feeding into the innovative performance of organizations at the micro level. At the macro level, the "cultural space" (LUNDVALL, 1992) draws together the institutional environment that enables individuals and organizations alike to decode relevant information and employ it in their innovation processes. As becomes evident from the diverse family of "territorial innovation models" assembled by MOULAERT and SEKIA (2003), this dimension of space overlaps considerably with territorial space. Indeed, many mechanisms commonly attributed to geographical proximity are in fact based on a relational concept of space (GERTLER, 1995). However, the overlap is by no means complete, since modern communications technology allows relational proximity to "be achieved at a distance" (AMIN, 2000).

– The concept of **institutional space** combines the organizational and relational dimensions by comprising both formal institutions (i.e. organizations or "players") and informal institutions, i.e. institutions in the narrow sense or "rules" in the words of NORTH (1994b). AMIN (2000) suggests that institutional proximity might be more important than territorial proximity in constituting what he refers to as "the 'soft' architecture of learning".

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– Furthermore, **temporal space** captures the notions that partners engaging in collaborative innovation projects need to have a roughly similar time horizon (LUNDVALL, 1998). This dimension can apply to intertemporal complementarities arising during the innovation process, as well as to a convergence of individual plans for the future, anticipations and behavioural patterns, which is frequently observed in co-operative projects (BLANC and SIERRA, 1999).

Among others, OINAS and MALECKI (2002) assume the various concepts of space to be substitutable, at least to a certain extent. The international organization of innovation by MNCs shows that organizational proximity combined with modern information and telecommunication technologies provides an alternative model of technology transfer that does not permanently rely on territorial proximity. MNCs use the organizational proximity to overcome the territorial and sometimes also cultural distance between their dispersed operations (RALLET and TORRE, 1998). To conclude, it remains unclear to what extent the various dimensions of space can be substituted for each other. However, the complex interactions between different dimensions of space render it unrealistic to expect interactive learning to be induced by territorial proximity alone, or "learning by being there" (GERTLER, 1995; HASSINK, 2001).

To summarise, our review of systems, scales and spaces of innovation allows us to derive four hypotheses to guide our empirical research:

H_1: Technological capabilities in Southeast Asia differ systematically from those found in Europe, as suggested by the stronger focus on the adoption and adaptation rather than the original production of technology.

H_2: Following from the systems nature of innovation, collaboration in innovation projects is as prevalent in Southeast Asia as in Europe.

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H_3: When applying innovation systems and other territorial innovation models such as industrial districts to Southeast Asia, the reviewed literature calls for a stronger integration of the international scale. It can therefore be expected to find innovation networks with international orientation more widespread than in Europe.

H_4: If some kind of proximity is taken as a necessary condition for interactive learning, actors in Southeast Asia must in some way substitute for the relative lack of territorial proximity when compared with Europe.

Research Methodology

Carried out in two phases between 1995 and 1999, the European Regional Innovation Survey (ERIS) aimed at empirically assessing the innovation behaviour of manufacturing firms, service providers and research institutions, as well their intraregional and interregional co-operation relationships, and at providing a comparative evaluation. For this purpose usable data were obtained from roughly 8,600 innovation actors in eleven European regions, including 4,200 manufacturing firms, 2,500 KIBS and 1,900 research institutions. STERNBERG (2000) introduces the ERIS study's theoretical foundation, methodology and sample details, while KOSCHATZKY and STERNBERG (2000) summarise the main findings, as well as their conceptual and policy implications. We transferred this established research methodology to selected metropolitan regions in Southeast Asia, with due adaptations to the specific regional settings[5]. The resulting questionnaires thus aimed at striking a balance between the best possible comparability and the main specifics of the survey regions to cover the following issues:

- General information: as an introduction, questions were asked about various firm characteristics such as age, size (in terms of turnover, fixed assets, and employees), industry, ownership and

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functional status, share of exports, educational profile of staff etc. In the analysis these variables can be called upon to explain differences in the innovation and co-operation behaviour.

- Innovation activities: *innovating* firms which had introduced a new or substantially improved product or manufacturing process in the past three years were asked to provide details concerning their innovation behaviour. Here, input indicators (personnel and expenditure on R&D and/or innovations) as well as throughput indicators (e. g. patents) and output indicators were recorded. A firm is considered *innovative* when new or substantially improved products contribute to at least 25 % of its turnover, or when 25 % of its output is produced with new or improved processes.
- Innovation co-operation: in this central part of the survey firms were asked which external sources of technical knowledge they used for their innovation processes, with which external partners they co-operated and where those partners were located. Here, the most important questions concern the connection between co-operation and innovation success as well as the territorial scales of innovation networks, including the relevance of territorial proximity to co-operation.

As a first attempt to trace regional innovation capabilities and cooperation relationships in Southeast Asia case study regions were selected in order to analyse contrasting national and regional settings using a harmonised methodological base. As shown below, the selected regions differ markedly in their economic, industrial and political structure. As a consequence, our results reflect these differences on a sound empirical ground. While the present paper aims at painting an overall picture across all manufacturing industries, REVILLA DIEZ and BERGER (2005a, 2005b) provide sector specific evidence. The choice of three leading manufacturing centres as case studies can hardly claim to be representative of other manufacturing bases in the region, let alone for Southeast Asia as a

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whole.

Singapore, the Thai capital of Bangkok and Malaysia's manufacturing centre Penang represent NIEs at different stages of development: while first-generation NIE Singapore ranks among the 30 most affluent countries in the world with a per capita income of 21,230 US$ in 2003, second-generation NIEs Malaysia and Thailand rank 82nd and 105th with a per capita income of 3,880 US$ and 2,190 US$, respectively (THE WORLD BANK, 2003). Despite these differences, Singapore, Penang and Bangkok are all urban-industrial agglomerations, and in this respect comparable to the 'Metropolitan Innovation Systems' of Barcelona, Stockholm and Vienna (ERIS-3; FISCHER, REVILLA DIEZ and SNICKARS, 2001; REVILLA DIEZ, 2002).

Carried out between 1999 and 2001, our postal surveys of manufacturing establishments in Singapore, Penang and Thailand yielded a return of 1,585 usable questionnaires. As Table 1 displays, sample sizes match those achieved in the European regions both in absolute and in relative terms, and in the case of Thailand they even surpass them. Structurally, all three samples reflect the structure of their respective manufacturing economies. With the exception of Penang where data on the total population could not be obtained, the samples are also broadly representative in terms of the size structure of responding firms[6]. In addition to these postal surveys, semi-standardized interviews with representatives of manufacturing establishments have been conducted in all three study regions; they are documented by KIESE (2004) for Singapore and STRACKE (2003) for Penang.

All three surveys received critical support from high-level public institutions: in Singapore, the powerful Economic Development Board (EDB; SCHEIN, 1996) adopted it as their first National Innovation Survey (WONG, KIESE, SINGH et al., 2003), while the Penang State Innovation Survey was officially backed by the State Government. The Thai survey was designed as a National R&D and Innovation Survey for the National Science and Technology Development Agency (NSTDA),

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covering the entire country[7]. However, 91.2 % of the firms participating in our survey are located in the Extended Bangkok Region comprising the Bangkok Metropolitan Region (BMR) and the Eastern Seaboard Region, and in the neighbouring Province of Ayutthaya, reflecting Thailand's highly uneven economic geography in general and more specifically the striking concentration of the country's innovation resources within the capital region. To ensure comparability with Singapore, Penang and the eleven European regions studied by ERIS, we will use this modified delineation of the Extended Bangkok Region (EBR+) for all further analysis.

[Insert table 1 about here]

Technological capabilities: Empirical evidence

Secondary data show that Singapore's technological capabilities improved rapidly during the 1980s and 1990s (table 2). The city state's gross expenditure on R&D reached 2.15 % of GDP in 2003, the highest value within Southeast Asia (A*STAR, 2004). The government has commonly seen 2005 as the target year for Singapore to close the remaining gap with most of the OECD countries, whose R&D intensity typically ranges between 2 % and 3 %. Through the expansion of the national R&D infrastructure and the massive recruitment of foreign scientists the city state was able to increase its relative endowment with researchers almost eightfold between 1980 and 2000, and with 4,140 researchers per million inhabitants it is comparable to Norway and does not rank far behind leading OECD countries such as Japan (5.095) or Finland (5.059 in 2000; OECD, 2002).

[Insert table 2 about here]

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In South East Asia's second-generation NIEs, on the other hand, a significant reduction of the technological gap has yet to be achieved: according to UNESCO (2004) data, only 0.49 % of GDP was spent on R&D in Malaysia in 2000, and in Thailand this was as little as 0.1 % in 1997, with no more recent data given. According to MASTIC, the Malaysian ratio has further improved to reach 0.69 % in 2002 (MASTIC 2004). The rudimentary data given in table 2 suggest that the gap vis-à-vis the industrialized countries has not narrowed substantially, and even widened for Thailand since 1980, and for Malaysia in the early 1990s. The relative number of researchers in Malaysia and Thailand also lay distinctly below the figure in Singapore in the middle of the 1990s.

While the data compiled at the national level confirm a rapid reduction of Singapore's technological gap when compared with the leading industrialized nations, a comparison of our surveys results with the ERIS data reveals that all Southeast Asian survey regions clearly lag behind at the firm level (Table 3). This gap is smallest when measured by the proportion of innovating firms: while in the ERIS regions an average of 78 % of all firms reported the introduction of a new or substantially improved product or manufacturing process, this figure was 39 % in Singapore, and 42 % in Penang. In contrast, formal R&D as well as the protection of intellectual property by patents play a less important role. The gap is, however, largest for the proportion of new products in turnover. While this amounts to 50 % in the European regions, in Singapore and Penang it is only around 12.5 %. If MNCs are excluded, this value drops to 8 %. In Bangkok, firms even attributed a mere 4.7 % of their turnover to new or significantly improved products. The increasing technological gap from input indicators to throughput and output indicators might imply that, on average, corporate innovation efforts are less efficient in Singapore, Penang and Bangkok than they are in European regions. Whether this less favourable input-output ratio is caused by internal management problems or by a

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more unfavorable external environment must be left unanswered here.

[Insert table 3 about here]

A comparison between the three Southeast Asian regions initially reveals that Penang and Singapore are at a similar stage of technological development despite Singapore's clear lead over Malaysia at the national scale shown above. Malaysia's 'Silicon Island' Penang hosts an important cluster of multinational electronics firms, in recent years facing increasingly competitive pressure from China. Penang has a higher proportion of innovating firms, but, on the other hand, a slightly smaller proportion of firms carrying out R&D and applying for patents. In contrast, Bangkok clearly trails behind Singapore and Penang regarding all the indicators captured in our surveys. Overall, these findings are consistent with the evidence from secondary statistics: Singapore has already achieved a higher technological stage of development than Penang and Bangkok, but Penang as a high-tech enclave is most certainly not representative of Malaysia as a whole.

Innovation as an interactive process

As discussed above, it has become commonplace in innovation research since the 1980s that innovation processes are characterized by a high degree of complexity and feedbacks in all their phases. "No business is an island" (HAKANSON and SNEHOTA, 1997) - this core statement of more recent innovation models is confirmed in the results of our surveys: almost all firms in Singapore, Penang and Bangkok co-operate with external partners in their innovation projects, while ARNDT and STERNBERG (2000, p. 481) found 10 % of firms in the ERIS sample to innovate in isolation. Roughly 90 % even confirmed intensive co-operation relationships with at least one partner (table 4).

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It can be stated that, as far as their innovation projects are concerned, firms in Singapore, Penang and Bangkok rely on co-operation more frequently than their European counterparts. Two explanations may be put forward for this: firstly, in accordance with the resource-based theory of the firm a greater propensity to co-operate may indicate a relative lack of innovation-relevant resources (PENROSE, 1959; WERNERFELT, 1984; PRALAHAD and HAMEL, 1990; FOSS, 1998). Secondly, it simply reflects the greater extent of external control as evident from the high share of foreign affiliates in our survey regions.

[Insert table 4 about here]

As in the ERIS regions, vertical co-operation patterns also prevail in Southeast Asia: the most important partners are customers, followed by suppliers and foreign parent companies. This confirms the view held in the literature that the most important channels of technology transfer to NIEs flow between MNC headquarters and their local subsidiaries, and also between local suppliers and their technologically advanced customers (in industrialized countries or locally-based MNCs). Variations in the relative importance of research facilities across the regions surveyed generally reflect their quantitative and qualitative availability, which is particularly poorly developed in Penang. In contrast, horizontal co-operation relationships with competitors or other businesses only play a minor role, as is the case in Europe.

Scaling Innovation Networks

The theoretical discussion leads us to expect that under certain conditions, such as at the early stages of innovation processes when a high proportion of the knowledge to be exchanged is not yet

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codified, territorial proximity does foster the interaction between innovation actors. Figure 1 compares the scales of co-operation by partners of manufacturing firms in Singapore, Penang and the three metropolitan ERIS regions of Barcelona, Vienna and Stockholm. In Bangkok, however, our survey did not cover the territorial distribution of collaboration partners. The network diagram distinguishes four territorial scales of co-operation: intraregional linkages, national collaborations, co-operations within the respective supranational economic spaces (Europe or ASEAN) as well as the interrelationships extending beyond them. While the area of the polygons can be interpreted as the importance of the co-operation partners, their shape indicates the territorial extent or range of the innovation-relevant collaborations.

[Insert figure 1 about here]

In the European regions, a distance-decay pattern can be observed, since the frequency of co-operations generally declines with increasing distance between the partners. Here collaborative relationships are concentrated equally on the regional and national innovation systems. The continuing relevance of the national scale is forcefully illustrated by the case of the neighboring ERIS regions of Alsace, France and Baden, Germany. Though they are only separated by the river Rhine coinciding with the national border and closely integrated economically, KOSCHATZKY (2000) found surprisingly little innovation-related interaction between the two regions. Rather than looking at their neighbouring region as a significant source of knowledge, firms' interactive learning processes still take place mainly within their own national and regional systems of innovation. As factors hindering closer cross-border interaction, SMEs from Baden cited problems in understanding the French institutional structure (e.g. addressing the right people or organization in an appropriate

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manner), different mentalities, French bureaucracy and centralism, and difficult market access due to the predominance of national suppliers. In this case, closeness in cultural and institutional space clearly outweighs territorial proximity.

In contrast, innovation co-operations on the global scale are not very common for manufacturing firms in Europe. Intraregional co-operations are particularly significant for co-operations with service providers and research facilities. While especially KIBS provide their services in close collaboration with their customers (HERTOG, 2002), collaborations with research institutions also tend to involve the exchange of mainly tacit knowledge as they tend to take place at the early stages of the innovation process. On the other hand, however, vertical co-operations with customers and/or suppliers along the value chain are more highly diversified across the territorial scales (REVILLA DIEZ, 2002), indicating that comparatively more codified knowledge at later stages of the innovation process is exchanged with them.

Collaboration patterns in the Southeast Asian regions are markedly different: the innovation-related linkages of manufacturing firms in Singapore and Penang display a discontinuous territorial pattern. 86 % and 68 % respectively of all the innovating firms maintain intensive co-operations with partners outside Southeast Asia, but only slightly more than 40 % with partners in the neighbouring ASEAN countries. Most firms thus ‘leapfrog’ the technologically less developed ASEAN countries and co-operate directly with partners in the leading technology regions in North America, Europe and Japan, confirming the theoretical assumption that the international scale plays a much greater role for collaborative innovation processes in NIEs. In Singapore, as in Penang, it can be observed that due to their embeddedness in sectoral innovation systems characterized by global production networks and market relationships, MNCs are strongly directed towards global co-operations. In contrast, customers in the region are the most important collaboration partners for local firms -

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presumably to a large extent MNC subsidiaries in Singapore and Penang. Given the high degree of interdependence between production and innovation networks, this evidence confirms findings of a survey of 63 Singapore-based manufacturing MNCs with cross-border operations in Southeast Asia. YEUNG (2001) found their spatial fragmentation of production rather limited. Instead, most of their subsidiaries were found to serve local markets, or manufacture components and parts for the regional production facilities of their major global corporation customers.

Despite the striking contrast in scalar patterns between the European and the Southeast Asian study regions, some differences between Singapore and Penang are worth pointing out. Co-operations at the national and global scales dominate in Singapore, while partners located in other ASEAN countries have hardly any significance. Broken down by collaboration partner, one finds the same picture as in the European regions surveyed: for the reasons mentioned above, co-operations with KIBS and research facilities concentrate predominately on the regional level, while vertical linkages along the value chain are most evenly spread over the territorial scales. The differences between MNC and local firms are rather gradual than of principle in Singapore: while MNC are generally slightly more strongly directed towards international collaborations, due to their smaller size local firms more frequently work together with KIBS, but more seldom with research facilities in their innovation projects.

Collaborations are less widespread among the innovating firms surveyed in Penang than they are in Singapore. The existing innovation-relevant linkages in Penang are directed world-wide to a greater extent, since the technological basis in the region is less developed than in Singapore. The latter is also important for the scales of co-operation according to partners: unlike in ERIS-3 or Singapore, vertical co-operations are still most strongly localized, and this applies especially to downstream linkages with customers. Collaborations with KIBS, which are strongly localized elsewhere, rather

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take place at the global level in Penang. Intensive co-operations with research institutions, which are significant in the early phase of the innovation process and thus particularly dependent on territorial proximity, are, in contrast, of practically no importance in Penang. These anomalies can essentially be attributed to supply gaps in Penang's technological infrastructure, most notably the still relatively poor endowment with KIBS and research institutions.

Given that the transfer of tacit knowledge and the re-contextualization of codified knowledge require close interaction of innovation actors in territorial proximity, how can the significantly greater prevalence of international innovation linkages in Singapore and Penang vis-à-vis Europe be explained? Interviews carried out with 17 manufacturers and five research institutions in Singapore's electronics sector (KIESE, 2004) provide a convincing explanation for this seeming contradiction: the innovation process is typically split up in territorial space in such a way that the early phases of the innovation process requiring intensive circulation of tacit knowledge in close territorial proximity mostly take place outside Singapore in the technologically more advanced home regions of the co-operation partners. Ideas for new products, concepts and also prototypes are usually developed in the R&D head offices of the MNC, where their basic research also takes place. For pilot production at the latest, new products or processes are then transferred to the sites of the leading manufacturing plants, such as Singapore. Since the technology is not fully consolidated and documented at this stage, the transfer still requires face-to-face contacts. Hence, firms create this physical proximity on a temporary basis by firms sending their scientists and engineers for visits abroad, in most cases lasting several months, in order for them to learn the new technology hands-on. Subsequent interaction and feedback is achieved using various means of telecommunication (e-mail, telephone, fax, video conferencing etc.). This process transforms previously tacit knowledge into a club good which can be traded globally within the respective "community of practice" (BROWN and DUGUID,

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1996; WENGER, 1999; AMIN, 2000), defined as a group of individuals informally bound together by shared experience or a common problem, thus producing new routines, conventions and norms through collective problem-solving, trial and error, and experimentation (GERTLER, 2001).

Furthermore, our interviews confirm that in processes of interactive learning, cultural distances in terms of language, communicative style, values (e.g. individualistic vs. collectivistic) and behavioural patterns need to be overcome. However, virtually all interviewees stressed that organizational space perceived as 'corporate culture' tends to dominate intercultural differences such as 'American vs. Asian' in the case of US-owned MNCs in Singapore, with 'Asian' meaning mainly ethnic Chinese dominating management and research staff in the city-state. This implies a basic difference between local firms and MNC subsidiaries: when engaged in interactive learning with their clients, local firms are not only tied into asymmetric power relationships, but also have to overcome greater distances in organizational space when compared to MNC subsidiaries primarily internalizing learning within their corporate network.

In sum, the innovation and co-operation patterns found in Singapore, Penang and Bangkok provide evidence for the continued strong dependence of these regions on external sources of knowledge, as well as their not yet fully developed endogenous capacities for the production of innovation-relevant knowledge. Among the countries and regions under study, Singapore is technologically the most advanced. Malaysia's high-tech enclave Penang already comes close to Singapore with regard to the innovation indicators at the firm level. However, co-operation patterns reveal a considerable need to improve the technological infrastructure, above all research facilities and knowledge-intensive services supporting corporate innovation processes, not least with the aim to root them locally in the face of intense locational competition.

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Conclusion

Our review of systems, scales and spaces of innovation allowed us to hypothesise that technological capabilities differ systematically from those found in Europe (H_1). Both secondary data and our survey evidence appear to support this assumption. The former indicate a rapid technological catching-up on the part of Singapore, while they reveal that Malaysia and Thailand still lag some way behind in their technological capabilities. Contradicting visions of technological leapfrogging, our firm-level survey results show that innovation activities are still less widespread in Singapore, Penang and Bangkok when compared with Europe. Singapore has already achieved a higher level of technological development than Malaysia and Thailand. Within Malaysia the high-tech enclave of Penang, however, has reached a technological level similar to that of Singapore, but the technological infrastructure of Malaysia's 'Silicon Island' has yet to be developed. Apart from the general 'technological gap', a comparison of the different input, throughput and output indicators also leads us to conclude that firms' innovation efforts are less efficient in Southeast Asia.

Following from the systems nature of innovation, we expected to find collaboration in innovation projects as prevalent in Southeast Asia as in Europe (H_2). Our survey results show that external co-operations are even more widespread in Singapore, Penang and Malaysia. For MNC subsidiaries the most important partners are their foreign affiliates, and for local firms they are technologically advanced customers ('lead users'). Thus, as in Europe, vertical collaboration patterns dominate. While in Europe, however, the frequency of co-operation declines with the increasing distance between the partners, a discontinuous territorial pattern predominates in Singapore and Penang. Innovating firms 'leapfrog' the technologically less developed neighbouring countries and co-operate directly with technologically leading partners in North America, Europe and Japan. This finding (H_3) supports the need for a stronger integration of the international scale when extending

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innovation systems and other territorial innovation models beyond the limited set of advances regions in developed countries for which they were originally developed.

However, this discontinuous territorial pattern of innovation linkages does not mean that territorial proximity does no longer play a role (H_4). It is rather created artificially by the temporary mobility of the participating scientists and engineers when tacit knowledge needs to be transferred in the territorially split innovation process.

Scaling Innovation: The Road Ahead

Our empirical findings suggest that the knowledge about localised processes of learning and innovation generated in successful regions of mature industrialised countries cannot be transferred to 'grey mass regions' in industrialised countries or even to NIEs or developing countries without modification. In contrast to the distance-decay patterns prevailing in the European study regions, the territorial patterns of innovation networks found in Singapore and Penang are discontinuous: innovating firms collaborate with local partners, or 'leapfrog' the neighbouring regions of Southeast Asia to work with technologically advanced partners in North America, Europe, or Japan. This finding supports the demand voiced by BUNNELL and COE (2001) that innovation networks should be analysed not only *on* specific territorial scales (international, national, local), but also and especially *between* these scales in order to grasp the cross-scalar nature of innovation.

However, our suggestion is that dealing with *territorial* scales alone is insufficient. As evident from our interview material, firms engaging in collaborative innovation projects do need the physical proximity of the individuals involved to exchange incompletely codified knowledge and engage in interactive learning processes. However, this proximity is not created 'naturally' by co-location, but 'artificially' by the temporal mobility of scientific and technical personnel. We sug-

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gest that *multi-dimensional spaces of interaction* made up by the various dimensions of space outlined above could be instrumental in developing our understanding of the relation of territorial versus non-territorial space in collaborative innovation processes, thus bearing the potential to analyse "how knowledge is actually transmitted, among whom, at what distance, and on the basis of which codebooks", a demand voiced by BRESCHI and LISSONI (2001, p. 255). Territorial or physical proximity can not only be generated temporarily, but also to a certain extent be substituted by other forms of proximity. Our interview findings from electronics firms and research institutions in Singapore suggest that in addition to techno-economic proximity, which is a necessary precondition anyway, organisational proximity is most critical to overcome territorial and cultural distances (H_4). On the impact of specific Asian cultures on innovation and collaboration, our research methodology only allowed for scanty evidence. Generally, more detailed studies into the relative importance and mutual interactions of the various dimensions of space are definitely needed, mapping each interaction in territorial, techno-economic, organisational, relational and temporal space.

Future research into the geography of collaborative innovation activities should thus not only focus on territorial scales and the interchange between them, but also include non-territorial dimensions of space. Great academic endeavour will be required to theoretically conceive multi-dimensional spaces of innovation, and to translate them into empirical research. The different dimensions offer a vast potential for interdisciplinary research that can only benefit the often challenged standing of economic geography as an academic discipline, especially in joint efforts with economists, innovation researchers and social scientists.

Avenues for Future Research

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Extending the ERIS research methodology to Southeast Asia allowed us to measure and compare firm-level innovation activities and to scale innovation networks in Southeast Asia on a representative empirical basis for the first time. High-level political support was absolutely critical to achieve acceptable response rates in all three study regions. Although face-to-face interviews were carried out following the postal surveys, more detailed case studies appear necessary to develop the understanding of innovation and co-operation activities in manufacturing firms in Southeast Asia.

In addition to this vertical extension, we can envisage three possible options for developing our research approach in the future. The *first* option is to further extend the pool of comparable data by studying sub-national regions hitherto not covered by innovation surveys. *Second*, the research presented here suffers from its essentially static perspective. Follow-up studies, possibly in the form of panel surveys, could for the first time generate representative time-series data on innovation activities and networks in Southeast Asia. *Third*, our research focuses on just one group of innovation actors, albeit presumably the most important one for TPP innovations. Including other groups of actors, such as knowledge-intensive business services or research institutions as in the ERIS project, would allow us to measure and scale innovation in Southeast Asia more broadly. To overcome the somewhat artificial boundary between the various groups of actors, most notably between manufacturing and services, future surveys might even choose a functional cluster approach to define their populations.

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Tables

Tab. 1 Project history and response rates (manufacturing only)

Region	Country	Year[1]	responses	response rate
Baden	Germany	1995	430	15.8%
Hannover-Brunswick-Göttingen	Germany	1995	372	20.6%
Saxony	Germany	1995	1,004	26.7%
Alsace	France	1997	263	15.0%
Barcelona	Spain	1997	395	15.3%
Gironde	France	1997	101	12.7%
Slovenia	Slovenia	1997	416	31.2%
South Holland	Netherlands	1997	261	13.7%
South Wales	UK	1997	280	17.6%
Stockholm	Sweden	1997	451	24.0%
Vienna	Austria	1997	204	19.9%
ERIS-11			***4,177***	***19.7%***
Singapore	Singapore	1999	374	20.0%
Penang	Malaysia	2000	192	20.8%
Bangkok	Thailand	2000	1,019	47.0%

1) launch

Data: European Regional Innovation Survey

EDB/NUS-CMIT National Innovation Survey Singapore

Penang State Innovation Survey

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Thailand R&D/Innovation Survey 2000

Tab. 2 Secondary innovation input data: Singapore, Malaysia and Thailand

a) Gross expenditure on R&D as a percentage of GDP

	1980	**1985**	**1990**	**1995**	**2000**
Singapore	0.26[1]	0.54[2]	0.86	1.16	1.89
Malaysia	n.a.	n.a.	0.40[3]	0.24[4]	0.49
Thailand	0.39	0.34	0.18	0.13	n.a.

1) 1981 2) 1984 3) 1992 4) 1996

b) Researchers per 1 million inhabitants

	1980	**1985**	**1990**	**1995**	**2000**
Singapore	485[1]	908	1.426	2.318	4.140
Malaysia	n.a.	182[2]	327[4]	93[6]	276
Thailand	n.a.	105[3]	87[5]	118	74[7]

1) 1981 2) 1983 3) 1987 4) 1988 5) 1989 6) 1996 7) 1997

Data: *UNESCO* 1999, 2004; *NSTB* (National Survey of R&D in Singapore, various years), MASTIC (http://www.mastic.gov.my, 2003-04-04)

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Tab. 3 Selected innovation indicators: Singapore, Penang and Bangkok vs. Europe

Innovation process		Input →		Throughput →				Output	
Region	Country	R&D[1]	Patents[2]	innovating[3]			innovative[4]		
				total	product	process	total	product	process
ERIS total		78.4%	24.1%	78.1%	69.5%	62.6%	n.a.	49.8%	n.a.
ERIS-maximum		88.5%	36.0%	93.9%	79.1%	79.3%	n.a.	66.0%	n.a.
ERIS-minimum		70.0%	10.3%	62.0%	49.0%	45.0%	n.a.	32.8%	n.a.
Singapore	Singapore	29.7%	7.8%	39.0%	30.2%	29.4%	19.5%	12.3%	15.7%
- local firms	Singapore	25.2%	5.%	31.2%	21.2%	22.8%	13.5%	8.1%	10.3%
- foreign firms	Singapore	37.2%	11.7%	52.6%	46.0%	40.9%	29.9%	19.7%	25.0%
Penang	Malaysia	26.6%	5.8%	42.4%	34.6%	38.7%	20.9%	12.6%	16.2%
- local firms	Malaysia	23.9%	3.7%	36.6%	28.4%	32.1%	14.9%	8.1%	12.7%
- foreign firms	Malaysia	32.8%	10.3%	56.1%	49.1%	54.4%	35.1%	22.8%	24.6%
Bangkok	Thailand	15.1%	2.2%[5]	17.8%	13.9%	12.8%	7.5%	4.7%	5.6%
- local firms	Thailand	16.1%	2.1%[5]	18.8%	15.4%	13.3%	7.6%	5.1%	6.1%
- foreign firms	Thailand	12.3%	2.3%[5]	14.6%	9.6%	11.2%	6.9%	3.5%	4.2%

1 Share of companies with R&D activities

2 Share of companies reporting patent applications during the previous three years

3 Share of companies having introduced new or substantially improved products or processes during the previous three years.

4 Share of companies with 25 % or more of sales (output) derived from new or substantially

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improved products (processes)

5 In Bangkok, only firms with R&D activity were asked for patent applications.

n.a. not available

Data: European Regional Innovation Survey, National Innovation Survey Singapore 1999, Penang State Innovation Survey 2000, Thailand R&D/Innovation Survey 2000

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Tab. 4 Share of innovating manufacturing companies collaborating *intensively* with external parties by type of partner

	Singapore (n=144)	**Penang (n=79)**	**Bangkok (n=177)**	**ERIS-3 (n=871)**
Any partner	92.4%	87.3%	88.7%	79.9%
Customers, buyers	67.4%	75.9%	70.1%	55.3%
Suppliers	46.5%	55.7%	60.5%	37.7%
Parent / affiliate company	58.3%	44.3%	42.4%	n.a.
Research institutions	27.1%	11.4%	21.5%	23.1%
Business service providers	13.2%	21.5%	12.4%	} 42.4%
Technical service providers	27.8%	38.0%	20.3%	
Competitors	9.6%	13.9%	16.9%	} 17.9%
Others	12.5%	6.3%	10.7%	

ERIS-3 metropolitan innovation systems of Barcelona, Stockholm, and Vienna

n.a. not available

Data: European Regional Innovation Survey, National Innovation Survey Singapore 1999, Penang State Innovation Survey 2000, Thailand R&D/Innovation Survey 2000.

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Endnotes

[1] The authors wish to thank two anonymous referees for their constructive comments. The usual disclaimer applies.

[2] The analyses presented are the result of research projects funded by the German Research Society (DFG) ("The Development of Regional Innovation Potential and Innovative Networks in Asia" DFG-code SCHA 198/38-1), as well as of numerous projects within the framework of the DFG priority programme "Technological Change and Regional Development in Europe" summarized by SCHÄTZL and REVILLA DIEZ (2002).

[3] Starting from the standard Oslo Manual definition of technological product and process innovations given in our introduction, manufacturing firms are traditionally seen as the core actors within an NSI as they generate new technological knowledge through formal research and development (R&D) and informal processes of learning, which they subsequently introduce to the market. Furthermore, they are also seen as prime users and adaptors of new technology. More recently, service firms have also been discovered as major sources of innovation provided that a broader concept of innovation is applied (MILES, 1994; DUCATEL and MILES, 1995; HOWELLS, 2001).

[4] More recently, the notion of proximity has spawned an increasing number of other writings, of which we would like to highlight BLANC and SIERRA (1999), HASSINK (2001), MORGAN (2004), as well as, BOSCHMA (2005) and TORRE and RALLET (2005) in a recent issue of this journal. As this emerging literature shows, the number and definition of relevant dimensions has not yet been fully agreed upon.

[5] Major adaptations relate to ownership structure, technological capabilities, absorptive capacity, innovation activities other than R&D, and firms' internal environment for innovation. While a detailed discussion would exceed the scope of this paper, the full questionnaires can be viewed in

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the appendixes of KIESE (2004) for Singapore and STRACKE (2003) for Penang.

[6] In Thailand, the firms were selected through random sampling stratified by size and industry. In Singapore and Penang, follow-up telephone calls to increase the response rate have been guided to make the structure of the sample reflect that of the total population (STRACKE, 2003; Kiese 2004).

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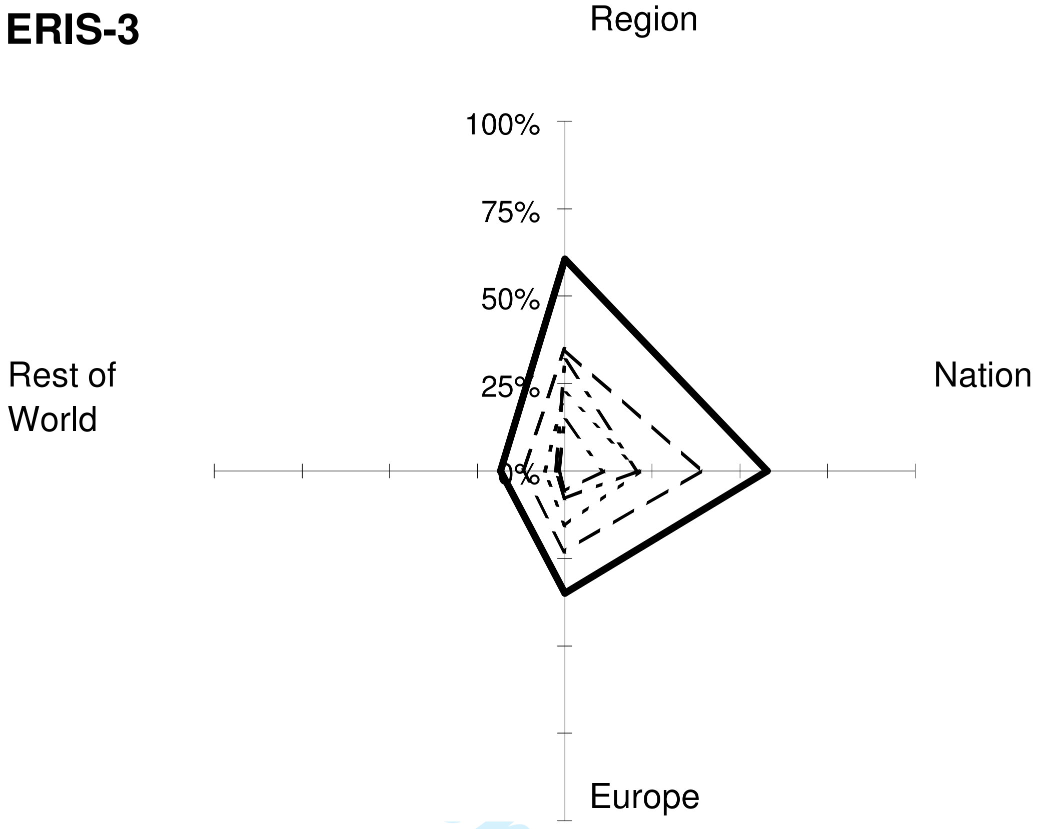
ERIS-3
Region
100%
75%
50%
25%
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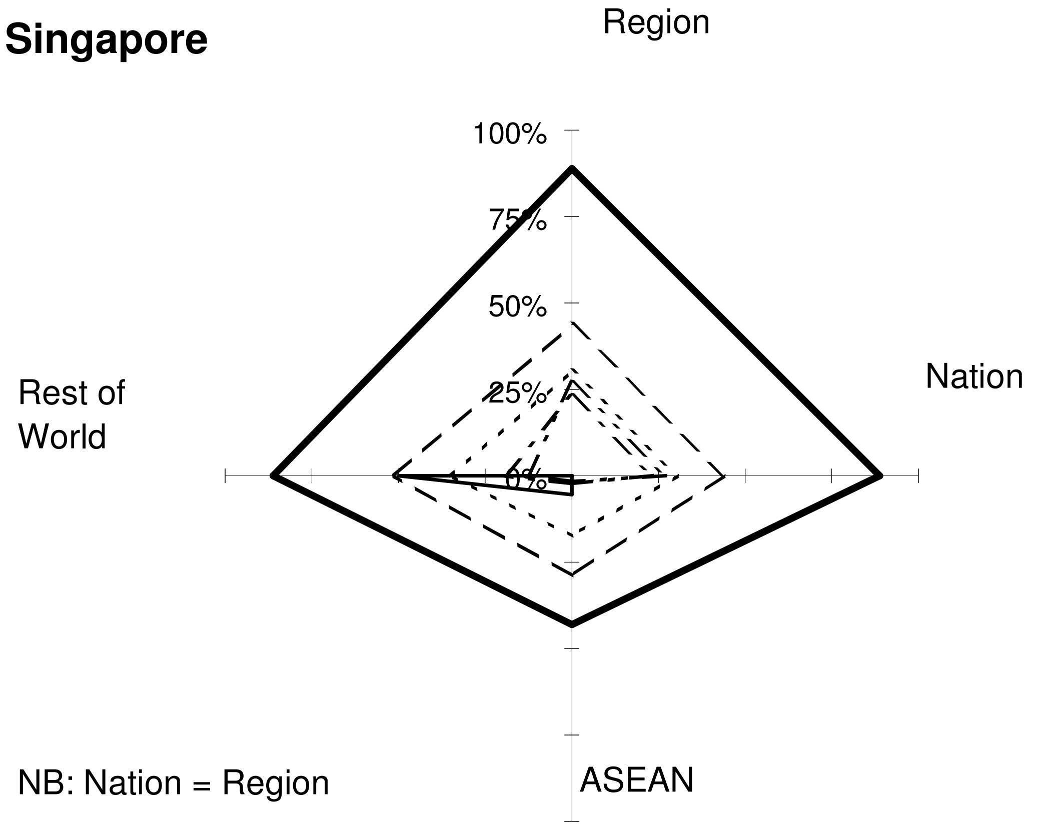
Rest of World
Nation
Europe


Singapore
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Rest of World
Nation
ASEAN
NB: Nation = Region

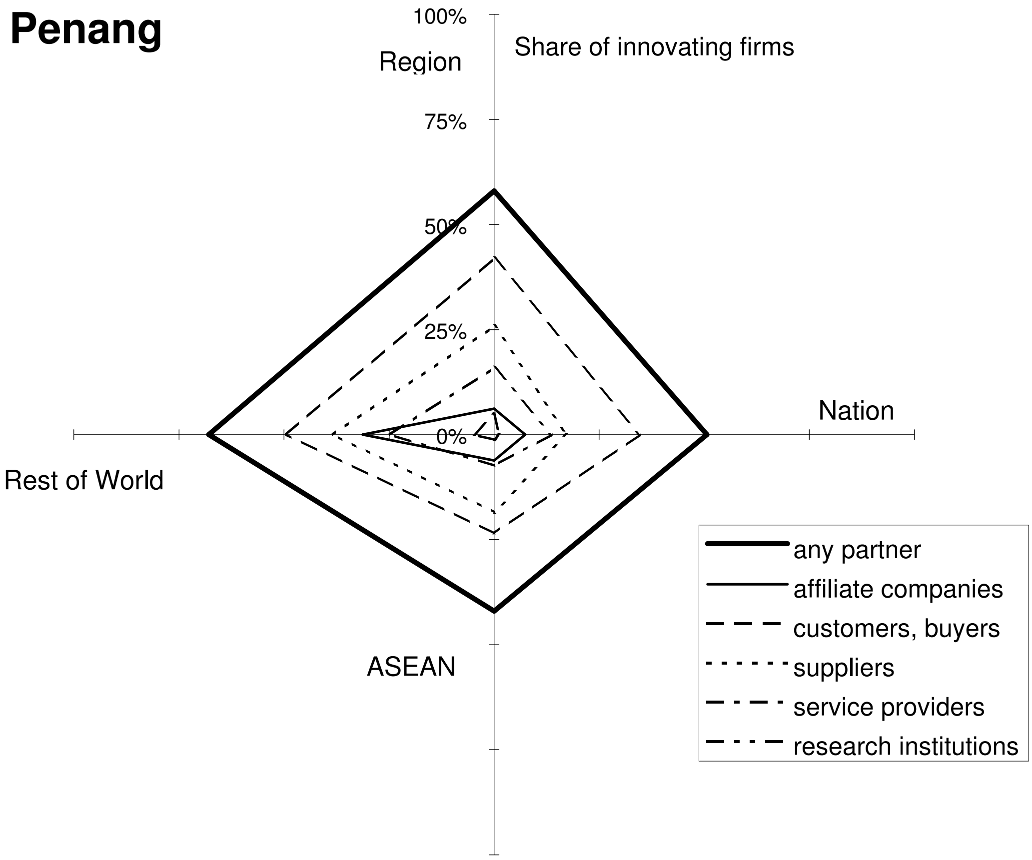

Figure 1: Spatial reach of intensive innovation-related linkages: Singapore and Penang in comparison with the metropolitan innovation systems of Barcelona, Stockholm and Vienna (ERIS-3)
110% = all innovating companies
Read as follows: In Penang, 42 % of all innovating firms work intensively with their customers or buyers.

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