

Innovation Policies and Locational Competitiveness : Lessons from Singapore

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Summary

The relationship between innovation policies and locational competitiveness has emerged as an important area in the analysis of economic development, reflecting both the centralisation and decentralisation of globalising economic activities. The underlying spatial and institutional components are subject to a pattern of cumulative causation in which strategic interventions of policy actors exercise a decisive role in shaping competitive advantages, while promoting interactions with local and foreign partners both from the private and public sectors. The Singaporean development experience illustrates these strategic interdependencies of innovation policies and locational competitiveness. Based on her role as a manufacturing and service hub, Singapore is viewed as an infrastructural nodal point which is interconnected to global production networks. Paralleling efforts in the domain of technological innovation, Singapore's policies for locational competitiveness aim at an adaptive harmonisation of the needs of international investors with local developmental objectives. This orientation characterises also current efforts in promoting Singapore as a knowledge agglomeration with a distinct science base, expanding R&D operations and an innovation-driven pattern of economic development. In conclusion, the locational rationale of Singapore's innovation policies provides lessons for dealing with the spatial and institutional implications of technological globalisation.

Key words : Singapore, competitiveness, globalisation, innovation policy, innovation system

1. Introduction¹⁾

Due to the globalisation of economic interactions and technological interdependencies, the relationship between innovation policies and locational competitiveness has emerged as an area of decisive importance for an analysis of the institutional dynamism of economic development. In this context, the present paper argues that the spatial and institutional aspects of the process of economic development are subject to a pattern of cumulative causation in which strategic interventions of policy actors exercise a decisive role, both in terms of the prospects and limits of sustaining competitive advantages. As globalisation drives an increasing complexity of the economic domain, the institutional foundations of these policy strategies involve diverse actors both from the public and private sector. More specifically, reflecting the establishment of global production and innovation networks, both foreign and local multinational enterprises have emerged as strategic partners of government. Moreover, as globalisation implies both a centralisation and decentralisation of economic activities, it drives institutional and spatial restructuring on various scales, highlighting the developmental role of high-level agglomerations. Accounting for the innovation-driven dynamism that is associated with these agglomerations, most prominently denoted as 'global cities', the strategic role of locational competitiveness in the local attraction of global knowledge and investment flows, promoted by specific innovation policies, becomes decisive for national and regional innovation systems.

The Singaporean development experience illustrates that interplay of innovation policies and locational competitiveness. Indeed, in order to sustain her competitive advantage as a regional business hub with a global reach, Singapore implements the developmental vision of a becoming an 'intelligent island' in a globalising knowledge-based economy. In particular, recent efforts in promoting the formation of a distinct science base have gained a prominent role in the strategic outlook of Singapore's innovation policy. In this context, a persistent problem is posed by the formation of institutions in support of knowledge spill-over effects among multinational and local enterprises, targeted as a crucial contribution to the formation of locally embedded capabilities. Thus, in dealing with globalisation by a responsive innovation policy, also the structural coherence of the local economy needs to be reconsidered.

This paper proceeds in three sections. First, the conceptual terrain is prepared from a

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neo-Schumpeterian perspective by exploring the matter of technological globalisation and its impact on systems of innovation, reflecting the rationale of locational competitiveness. Second, the Singaporean development experience and current attempts of sustaining its dynamism by implementing innovation policies with a conceptual bias towards locational competitiveness are taken to the fore. Third, the Singaporean system of innovation is explored; pinpointing the adaptive relationship between local government and multinational enterprises as an essential characteristic that shapes attempts of building a local science and technology infrastructure. The paper concludes that coping with globalisation offers persistent challenges for the Singapore economy, while providing general lessons for understanding the relationship between institutional and spatial factors in economic development.

2. Technological Globalisation and the Restructuring of Innovation Systems

Proponents of post-national constellations in a 'borderless world' usually define globalisation by components like the establishment of international capital markets, the formation of global industrial structures in supply, production, and sales, the dynamism of information and communication technologies, as well as the convergence of consumption standards (Ohmae, 1995: 3). Still, the actual pattern of globalisation points to the complexity of distinct institutional, technological and spatial processes that combine tendencies of decentralisation and centralisation. The fundamental role of technological innovation as a driving force in these processes is well captured by the aspect of technological globalisation, for an increasing proportion of technological innovations is exploited in international markets, while global technological collaboration expands. The global generation of technology, however, reflects only a partial internationalisation of technological activities, as these remain biased towards home country locations (Archibugi and Michie 1995: 125n). Globalisation then implies that Northern America, Europe, and East Asia emerge as the decisive world regions in terms of production, investment, and trade, with the United States as the dominant economy in technological terms, as indicated by the lead position in gross expenditures on R&D (Ebner, 2002).

The underlying innovation networks of multinational enterprises contain a range of functions from market oriented product development to basic research units. The latter tap spatial agglomerations of knowledge-intensive units such as excelling academic centres, perceived as 'pockets of innovation' (Granstrand et al. 1993: 414). Accordingly, technological globalisation implies the institutional and technological integration of geographically dispersed and locally

specialised activities (Cantwell, 1999: 238). High-level agglomerations in 'global cities' express that process, for they obtain interrelated functions as coordination points of the world economy, key locations and market places, and major sites of production and innovation (Sassen, 1994: 4). The related notion of 'technopoles' points to districts which are primarily located in metropolitan areas, providing agglomeration dynamics in high-technology industries through a specific 'milieu of innovation'. Exhibiting control functions with a global reach, they highlight a persistent drive for territorial specialisation concerning knowledge-intensive activities (Castells, 1996: 389). Locational competitiveness in terms of the territorial attraction of high-value added economic activities then depends on competitive advantages like the institutional setting of a specific territory that is crucial for embedding local innovation capabilities. Accordingly, local access to the global networks of multinational enterprises becomes crucial for sustaining economic development (Amin, 1994: 25). As a result, the particular logic of these global networks constrains developmental policy initiatives, enforcing an adaptation to the rationale of locational competitiveness.

The neo-Schumpeterian concept of techno-economic paradigms in economic development provides further insights concerning the institutional, technological and spatial dimensions of globalisation. A techno-economic paradigm denotes the ideal typical productive organisation and the related form of productivity growth within and across firms, industries and countries. Paradigm change then provides opportunities for catch-up growth (Freeman, 1996). Technological globalisation and the corresponding policy rationale of locational competitiveness thus may be assessed as reflections of a changing techno-economic paradigm. Such a comprehensive type of economic change affects also the structuration of national and regional innovation systems, which contain institutional networks and related interactions for the generation and diffusion of innovations within a territorial setting (Ebner, 1999: 143). On the firm level, these interactions denote primarily user-producer relationships, perceived as modes of cooperation between producers and users of certain innovations in terms of interactive learning (Lundvall, 1992: 47). Industrial structures and institutional set-up then determine the shape and performance of an innovation system, with institutional components like R&D facilities, education programmes and patent systems as decisive determinants of international competitiveness. Thus, systems of innovation are essential for coping with the developmental opportunities that are associated with changes of a techno-economic paradigm, pointing to infrastructural investments and institutional adaptations in support of learning processes (Dosi, Freeman and Fabiani, 1994: 11). Ideally, this type of learning is accompanied by procedures of 'unlearning' in terms of a comprehensive restructuring of institutional networks (Maskell and Malmberg, 1995: 25).

The provision of appropriate institutional conditions for technology transfer then denotes a

key problem of catch-up growth. Actually, firms in latecomer economies tend to reverse the pattern of technological trajectories that is associated with developed economies, ranging from basic production and incremental process change via design, process and product innovations to competitive R&D (Kim, 1999: 114). Yet adaptive technological learning may result in stagnation when the technology frontier is approached with a lack of local capabilities (Amsden and Hikino, 1993: 159). These technological capabilities are embodied in economic agents and the institutions that enable as well as constrain their activities. They are an outcome of institutional factors such as incentives, regulations and legal frameworks which accompany the material basis for innovation (Lall, 2000: 14). The East Asian development experience illustrates the evolution of these capabilities in constellations of techno-economic paradigm change quite well, highlighting the role of government initiatives in promoting innovation policies that have played a decisive role in catch-up growth (Chang, 1994: 298).

However, globalisation has fuelled both an internationalisation and regionalisation of innovation systems. The decreasing policy competence of nation-states in governing globalisation by means of 'techno-nationalism' parallels the emergence of regional or transnational ensembles as well as industry-specific patterns of interaction on a global scale (Nelson and Rosenberg, 1993: 17). National systems of innovation thus may be styled as segmented layers of institutions and production modes which integrate regional and local ensembles, such as technopoles, with their particular technological and institutional logic (Garrouste and Kirat, 1995: 235). This is in accordance with the suggestion that economic and political modes of interaction on the national level remain essential, accompanied by local, regional or supranational levels of interaction (Freeman and Soete, 1997: 315). Accordingly, due to its unparalleled institutional impact, the nation state may become subject to an extension of strategic partnerships with multinational enterprises (Chesnais, 1992: 265).

Indeed, as globalisation implies an increasing structural openness of economies, it puts into effect an outward orientation that is transmitted as a competitive pressure for reflexive adaptation. This may imply a drive for entrepreneurial orientation in both the private and public sector (Ebner, 2000). Corresponding development strategies highlight the international restructuring of innovation systems with a focus on attracting foreign direct investment, supporting the international expansion of local enterprises and promoting local technological specialisation (Niosi and Bellon, 1996). In particular, the restructuring of innovation systems involves a drive towards commercialisation on the grounds of transnational private-public partnerships (Galli and Teubal, 1997). These efforts underline persistent attempts of building alliances between local authorities and transnational capital, especially on the structural, meso-economic level of interaction (de

la Mothe and Paquet, 1996: 26).

These developmental aspects of innovation policies and locational competitiveness are well represented by the case of Singapore, the Southeast Asian city-state which has managed to proceed from the status of an underdeveloped economy towards a developed economy status during a thirty years period since 1965. In recent debates on the East Asian development experience, Singapore has been singled out as a successful example of industrial policies promoting development efforts by strategic interventions (Soon and Tang, 1993: 18). Yet more specifically, Singapore's economic development exhibits both structural and spatial features that need to be taken into account. With regard to its position as a manufacturing and service hub, Singapore is viewed as an infrastructural nodal point that is interconnected to transnational business networks, promoting a 'pragmatic adaptation' to changing conditions of the world economy (Castells, 1988: 10). Singaporean policies in support of locational competitiveness have been characterised as attempts to adjust and restructure the city-state in accordance with the needs of international investors that should harmonise with local objectives (Ho, 1993). Moreover, allowing for the spatial components of technological globalisation, Singapore has been characterised as a role model for the development of a combined global city-technopole complex, that is, as a model of innovation-based development strategies in globalisation (Castells, 1996: 390). Therefore, despite Singapore's status as a city-state type of small open economy, it may be argued that her case provides general lessons for the problems of economic development in globalisation.

3. The Institutional Foundations of Singapore's Development Trajectory

From the colonial epoch to the modern era of globalisation, Singapore's development has been subject to external influences on an international scale that have marked its institutional and spatial dynamism. Indeed, Singapore's evolutionary trajectory from a staple port at the southern tip of the Malayan peninsula to a global business agglomeration highlights the impact of a favourable location in the setting of international economic relations that made Singapore part of the major naval trade routes and corresponding communication networks since the 19th century. Already the establishment of Singapore as a trade post by the British had been pursued for logistical motives (Huff, 1994: 7). The corresponding outward oriented growth mode of a re-export economy persisted after Singapore's independence, then also reflecting a favourable international setting with expanding trade and investment flows that benefited all the Asia-Pacific newly industrialising economies (Islam and Chowdhury, 1997: 10). After all, with her three million

resident inhabitants, the city-state of Singapore currently represents the smallest of the East Asian newly industrialising economies regarding territory and population, while exhibiting their highest GNP per capita and obtaining a comparatively favourable position with regard to other development indicators (World Bank, 2000: 230).

The growth of aggregate output from 1965 to 2001 was indeed impressive, as Singapore's GDP at 1990 market prices multiplied by almost 18 times, while per capita GNP at current market prices multiplied by 23 times (Department of Statistics, 1996a: 2; 1996b: 4; 2000: 2; 2001: 2). Accordingly, from the 1960s to the 1990s, average annual growth rates of GDP performed in a range from 8% to 10%, expressing a sustained hyper growth of national income (Low et al 1993: 30n). Moreover, gross fixed capital formation grew at an average annual rate of 11% from 1965 to 1995, paralleled by exceptional savings rates which increased from a share of 11% GNP in 1965 to 50% during the 1990s (Department of Statistics, 1996b: 3; 2001: 2). Recession phases in the early 1970s, the growth slowdown of the mid-1980s, and the Asian financial crisis in 1997 could not revert the growth process, which has been highly dependent on foreign markets, especially in the United States and Japan (Ministry of Trade and Industry, 2001: 14). Macroeconomic stability has supported the fundamental role of the external sector with its foreign trade volume that has tended to exceed GNP by three times (Soon and Tan, 1993: 34).

Corresponding structural changes in the composition and contribution of sectors and industries have resulted from an expansion of the manufacturing industries, with almost half of their output and value added provided by electronic products and components during the 1990s (Department of Statistics, 2000: 88). Still, reflecting both the outstanding role of services in the activity profile of local enterprises as well as the expansion of an international segment of financial and business services, almost 70% of Singapore's GDP are made up of service activities (Ministry of Trade and Industry, 2001: 14). The service sector obtains an equally high employment share in total workforce allocation, with a majority of the workforce absorbed by local small and medium-sized enterprises in the private sector, which tend to operate on comparatively low productivity levels (Ministry of Trade and Industry, 2001: 21, 61). Thus, decisive impulses for Singapore's development trajectory have been provided by multinational enterprises in replacing the growth pattern of a staple port economy (Huff, 1994: 299). Since the 1970s both the foreign and the local sector experienced an expansion of net investment commitments in manufacturing industries, with the foreign sector accounting for a share of almost 70%. Parallel increases of foreign equity investment in financial services underline Singapore's global city status (Department of Statistics, 1996b: 14). Accordingly, in building competitive capabilities from sustained learning

effects, the local sector is highly dependent on interactions with multinational enterprises as strategic partners (Hobday, 1995: 136).

However, also the segment of government-related enterprises proves to be decisive in expanding local industrial and service capabilities. Indeed, complementing its distinct policy measures, Singapore's government regulates market processes also through its influence on the management of government-linked enterprises like Temasek Holdings. Despite efforts in privatisation and deregulation, government-linked enterprises still account for the bulk of high value-added activity of local firms. They also shape the strategic promotion of outward investment flows of Singaporean enterprises, thus contributing to the globalisation of the Singapore economy (Yeung, 1998: 405). The strategically exposed role of Singapore's government and public sector then points again to the correspondence of developmental strategies and the rationale of locational competitiveness, which also informs the key concern of the corresponding type of innovation policies.

Indeed, following the factual expulsion from the Malayan Federation in 1965, Singapore attempted to combine the autonomy of a nation-state with the locational character of a city-state. Confronted with comparatively poor endowments in physical and human capital, the Singaporean government attempted to capitalise on infrastructural assets inherited from the British, primarily the port and its refinery equipment (Huff, 1994: 273). Following the rationale of locational competitiveness, Singapore's government has aimed at attracting foreign direct investment by providing an institutional and infrastructural environment that should conform to the needs of international investors. Labour-intensive foreign direct investment as a means of creating employment dominated since the mid-1960s, moving gradually to a more capital-intensive investment pattern in the mid-1970s, which implied a shift in the provision of investment incentives (Rodan, 1989). In the aftermath of the recession in 1985, and also due to the emergence of locational competitors in the ASEAN area and beyond, Singapore's government turned to a strategy of providing opportunities for high value-added business activities, primarily knowledge-intensive segments (Islam and Chowdhury, 1997: 206).

The complex array of economic policies associated with that development strategy represents a flexible and pragmatic approach towards maintaining competitiveness. The support of a continuous upgrading of the value-added operations of the subsidiaries of multinational enterprises, and local enterprises interacting with them, should involve spill-over effects as well as self-directed benefits. Moreover, not only structural policies, but also monetary and fiscal policies have been subordinated to the primacy of maintaining locational competitiveness. Thus, the corporatist regulation of nominal wages and industrial relations through Singapore's National Wages Council has been perceived as a major locational policy instrument (Chew and Chew, 1996). However,

while the immobile factor land and the comparatively immobile factor labour have been subject to intense regulative interventions, the mobile factor capital is regulated through indicative measures, involving a broad range of material incentives (Huff, 1994: 339). An institutional lack of rent-seeking behaviour in the determination of market interventions seems to have contributed decisively to the implementation of these strategies (Bercuson et al., 1995: 18).

In addressing the developmental role of the state, the Economic Development Board EDB may be perceived as the core organisation in Singapore's policy networks with a leading function in the hierarchy of government boards. It has been continuously guiding Singapore's development trajectory under the motive of 'strategic pragmatism', that is the practice of matching the strategic interests of government with the corporate needs of international investors (Schein, 1996). The EDB was primarily concerned with the provision of industrial estates in the 1960s, then evolving as a major organisation in Singapore's development planning in the 1970s and heralding restructuring efforts of the 1980s towards higher value-added operations in targeted industries. This implied a broader approach to service provision in cooperative interactions with multinational enterprises since the 1990s, coordinated by the EDB with other government boards and agencies (Low et al., 1993: 63). Eminent were also learning efforts regarding policy orientation and implementation. The high-wage policy in the early 1980s, for instance, was originally initiated in order to support the relocation of labour-intensive manufacturing, while promoting a local expansion of high value-added production segments. However, this policy was confronted with an actual shortage of skilled manpower, accompanied by an unwillingness of foreign investors to comply with the wage constraints imposed by government. All of this contributed to an economic downturn in 1985 (Yun, 1998: 381). The subsequently formulated policy reorientation towards technological upgrading by means of distinct innovation policies should reinforce the participation of foreign investors in local policy networks. This responsiveness mirrors a continuous 'reinvention' of governance mechanisms as a key indicator of Singapore's state capacity (Low, 1998: 269).

Accordingly, the government report on Singapore's competitiveness that responded to the mid-1980s recession dealt primarily with cost competitiveness, focusing on wage regulation, whereas long-term development was said to be based on maintaining Singapore's role as a business and service hub. In this framework, the expansion of R&D activities was reconsidered with regard to tax incentives and funding schemes, accompanied by the provision of manpower and R&D infrastructures (Ministry of Trade and Industry, 1986: 147). Subsequent government proposals like the 'Strategic Economic Plan', published in 1991, reiterated these motives by promoting a policy programme, which set the vision of attaining the status of a developed economy by the year 2030. Highlighting the need for an innovation-driven development pattern, this should

imply the expansion of institutional networks for innovation, facilitating the formation of infrastructures for dealing with an evolving knowledge-intensive techno-economic paradigm. Strategic thrusts included the enhancing of human resources through education and training, the corporatist integration of interest groups, international access to knowledge infrastructures and networks, as well as the promotion of an innovative milieu with skilled manpower and R&D facilities (Economic Planning Committee and Ministry of Trade and Industry, 1991: 57). Conceptually, this perspective on innovation policy and locational competitiveness referred to Michael Porter's cluster approach to the competitive advantage of nations, which underlines the systemic nature of institutional conditions, industrial linkages and locational factors. Porter had actually suggested that Singapore would perform at a factor driven stage of economic development, lacking from 'home base' qualities for competitive local industries (Porter, 1990: 566).

As these proposals heralded the emergence of a distinct innovation policy, they led to the establishment of a National Science and Technology Board NSTB and the corresponding formulation of a 'National Technology Plan' in 1991, which announced the strategic promotion of applied innovation activities through the selective funding of R&D and the provision of manpower and institutional infrastructures (National Science and Technology Board, 1991). These measures were accompanied by industrial strategies regarding the formation of manufacturing and service clusters, accompanied by the redevelopment of local enterprises with the aim of productivity enhancement. In addressing unit labour costs, productivity and profitability, persistent efforts in structural diversification regarding 'home base' qualities for multinational and local enterprises were highlighted, with multinational enterprises perceived as long-term partners in the process of economic development (Economic Planning Committee and Ministry of Trade and Industry, 1991: 71). Due to a perception of localisation and regionalisation as facets of globalisation, multinational enterprises were even assisted in their relocation efforts throughout Asia. Regionalisation, in particular, was addressed as a policy focus by the 'growth triangle' strategy of establishing special zones for labour-intensive manufacturing processes in Johor and Riau, the border-regions of Singapore's land and labour affluent neighbours Malaysia and Indonesia. Furthermore, local enterprises have been encouraged to build up ventures overseas in supporting Singapore's role as a regional business hub (Low, et al., 1993: 157).

In terms of policy implementation and industrial specification, all of this was translated into specific assistance schemes for cluster development, innovation support, business service incentives, and schemes for the funding of overseas infrastructural projects, administered by the Economic Development Board (Economic Development Board, 1996). A related cluster development initiative that was launched in 1999 under the label of the 'Industry 21' plan then highlighted information

technology and life sciences as excelling areas for further developmental efforts (Economic Development Board, 2000: 10). Furthermore, in agreement with the perception of an emerging techno-economic paradigm based on information technologies, Singapore should become an 'intelligent island', endowed with a competitive national information infrastructure (National Computer Board, 1992). Related policies have been marked by efforts in deregulation and privatisation of the telecommunications sector, paralleled by a refinement of infrastructural facilities and services, as illustrated by the 'Singapore One' initiative in establishing an economy-wide broadband network that coincides with operations in strategic domains like e-commerce and e-government (Ministry of Trade and Industry, 2001: 78). These activities underline the blending of Singapore's development strategies with distinct innovation policies that address the locational aspects of international competitiveness, as mirrored by the evolution of the Singaporean system of innovation.

4. Singapore's Innovation Policies and the Rationale of Locational Competitiveness

The Singaporean system of innovation combines the policy capacity of a nation-state with the socio-economic features of a global city. It leverages on foreign direct investment, as multinational enterprises dominate R&D activities in the private sector, while local firms performing R&D activities comprise of diverse types like small and medium-sized enterprises in the supporting segment of multinationals, government-linked companies in technology-intensive industries, and private sector start-up firms in promising technology sectors (Wong, 1995: 15). Accordingly, policy efforts in building the innovation system are concerned with establishing bridging institutions that facilitate knowledge spill-over effects. They combine the rationale of locational competitiveness with a cooperative approach to knowledge formation and skills development, thus highlighting the key role of the education sector as well as the requirement for a continuous provision of skilled manpower that should benefit the developmental goal of moulding a knowledge-based economy.

Singapore's government administers its innovation policy primarily through the Economic Development Board as a core institution that exercises a broad strategic influence, in particular by means of investment schemes, whereas the organisational domain of R&D and related science-based activities is subject to the Agency for Science, Technology and Research, ASTAR, since 2002 serving as successor of the National Science and Technology Board. The underlying emphasis on service provision reflects the policy goal of transforming Singapore into a

technologically advanced business hub, with a local science-base that should complete a 'total business centre' strategy (Economic Planning Committee and Ministry of Trade and Industry, 1991). Accordingly, schemes for attracting high value-added business headquarter functions have been accompanied by research grants and fiscal incentives for the support of innovation activities, benefiting companies like Hewlett-Packard and Philips which have set up their regional R&D centres in Singapore and expanded their local production and service capacities, yet also addressing local firms in their expanding innovation efforts. In particular, grants like the Research Incentive Scheme for Companies and the Innovation Development Scheme accompany fiscal schemes for the tax deduction of R&D expenditures. However, the impact of these programmes regarding R&D and related activities is paralleled by the problem of supplying adequate resources for education and training that fit an increasingly knowledge-intensive type of production (Mani 2002: 128n).

With regard to innovation performance, output indicators like granted patents have been approaching the Hong Kong level of activity recently, as far as patents granted in the United States are concerned (Mani, 2002: 124). This reflects efforts in building the local science base. Expenditure on R&D as well as R&D manpower then may serve as innovation input indicators. As Table 1 depicts, Singaporean efforts in expanding R&D operations are evident. Gross expenditure on R&D - that is, GERD - increased 30-fold between 1981 and 1999, reaching a volume of \$2,656 million in 1999. This corresponds with a growth of the GERD to GDP ratio from 0.26% in 1981 to 1.84% in 1999 (National Science and Technology Board, 2000: 3). Still, despite the fact that benchmarking efforts with reference to global cities and metropolitan regions would provide more suitable material for a comparative assessment of innovation indicators, it is repeatedly claimed that the Singaporean system of innovation exhibits a 'GERD lag' as compared with other East Asian newly industrialised economies (Masuyama, 1997: 3).

As a Singaporean specificity, firms of a private sector structurally dominated by multinational enterprises account for two thirds of gross expenditure on R&D. Between 1990 and 1999 alone, private sector R&D expenditures increased by 5 times from 309 million Singapore Dollars to 1670 million Singapore Dollars (National Science and Technology Board, 2000: 9). Regarding industrial specialisation, private sector R&D spending in 1999 concentrated on engineering sciences, with a focus on the electronics, electrical, and mechanical segments, accompanied by computer and related sciences, as well as by chemical science. This reflects the impact of the lead industries in the manufacturing sector, and thus the congruence of the dominant pattern of R&D with industrial production. R&D expenditures in the public domain, including government, higher education and public research facilities, also seem to follow this pattern, as they are shaped

by the industry-specific articulation of private sector concerns for the commercial application of new knowledge. Accordingly, the bulk of R&D expenditures is dealing with experimental development and applied research, amounting to 86% of total expenditures, whereas pure and strategic types of basic research amount only to 14%, with a strong presence in public research facilities and higher education (National Science and Technology Board, 2000: 10). Thus, the developmental strategy of expanding the local science base does not yet coincide with the established pattern of industrial innovation activities.

Table 2 depicts R&D expenditures by industry group, as contributed by local and foreign companies in 1999. These data need to be interpreted with the caveat that NSTB statistics define local ownership by a 30% margin, which makes research consortia and joint ventures with a strong qualitative impact of multinational enterprises more difficult to assess. Evidently, multinational enterprises take the lead in providing the Singaporean innovation system with R&D impulses. This is immensely relevant in those industries which are associated with technologically advanced production segments, as the local content of R&D activities amounts only to 31% in electronics and to 20% in chemicals, well below the average 42% level of the whole manufacturing sector. This pattern underlines the assessment that international contributions to knowledge generation and dissemination characterise the Singaporean innovation system.

Table 1 : Innovation Input Indicators in Singapore, 1981-1999

Year	Gross Expenditure on R&D (\$M)	GERD/GDP Ratio (%)	Research Scientists and Engineers per 10,000 Labour Force
1981	81.0	0.26	10.6
1990	571.7	0.86	27.7
1991	756.7	1.02	33.6
1992	949.3	1.19	39.8
1993	998.2	1.07	40.5
1994	1,175.0	1.10	41.9
1995	1,366.6	1.16	47.7
1996	1,792.1	1.39	56.3
1997	2,104.6	1.50	60.2
1998	2,492.3	1.80	65.5
1999	2,656.3	1.84	69.9

Sources : Ministry of Trade and Industry (1997), *National Science and Technology Board* (2000: 3).

Table 2 : R&D Expenditures of Local and Foreign Companies by Industry, 1999

Industry Group	(1) Foreign Companies (\$M)	(2) Local Companies (\$M)	(3) Total (\$M)	(2)/(3) %
Manufacturing	780.99	585.05	1366.05	42
Electronics	518.32	237.80	756.12	31
Chemicals	99.89	26.69	126.58	20
Engineering	102.41	237.73	340.14	69
Precision Engineering	84.13	191.93	276.05	69
Process Engineering	6.02	3.72	9.74	38
Transport Engineering	12.26	42.09	54.35	77
Life Sciences	58.55	31.13	89.68	34
Light Industries/ Other Manufacturing	1.82	51.71	53.52	96
Services	151.84	152.98	304.82	50
IT/Communications	71.17	105.70	176.87	59
Finance and Business	18.98	12.25	31.23	38
Other Services	61.69	35.03	96.72	36
All Industry Groups	932.83	738.03	1670.86	44

Notes : Definition of local: 30% or more locally owned; definition of foreign: less than 30% locally owned.
Source : National Science and Technology Board (2000: 34); calculations by author.

In this context, implementing the developmental goal of turning Singapore into a knowledge-intensive agglomeration points to the role of academic centres of excellence with access to the global innovation networks of multinational enterprises and their high-level knowledge flows. Complementing applied and production-related R&D operations, the establishment of a local science base becomes crucial for sustaining Singapore's locational competitiveness under the conditions of technological globalisation; a position that reflects a specific thrust in Singaporean development strategies since the formulation of the 'Strategic Economic Plan' in 1991. The evolving science base of Singapore's innovation system is founded on interactions among private and public as well as local and international agents, with an exposed role for institutions of tertiary education and affiliated research institutes. Indeed, Singapore's innovation policies have recently promoted the establishment of R&D facilities in the education sector, providing a knowledge

infrastructure for collaborations with multinational corporate partners, while supporting a local segment of entrepreneurial spin-off ventures in knowledge-intensive industries. These research institutes and centres represent an institutional cornerstone of Singapore's development strategies (National Science and Technology Board, 1999).

In accordance with the outward-oriented character of the Singaporean innovation system, universities and polytechnics are engaged in cooperative R&D efforts with multinational enterprises, well in addition to the operation of training facilities that have been set up in cooperation with foreign enterprises as well as foreign government agencies (Ebner, 2004: 67). This is exemplified by the formation of a R&D cluster in the 'Technology Corridor', set up in the Southwest of Singapore as a connection of the Jurong industrial estates, prominent in locating manufacturing operations of multinational enterprises, with the surrounding universities and polytechnics, accompanied by neighbouring business, service and science parks. The expansion of the science park located next to the main campus of the National University was announced as a first step in developing that 'Corridor', with further expansions under way (Economic Development Board, 1996).

The National University of Singapore is not only the leading academic organisation in higher education; it is also a decisive player in university-industry collaboration on applied R&D. It provides a campus location for regionally outstanding research institutes, such as the Institute for Systems Science, the Institute for Molecular and Cell Biology and the Institute for Microelectronics, pointing to a research focus on information and communication technology, microelectronics as well as life sciences. These institutes co-operate with multinational enterprises and international research partners, covering a range from contract research to mutual agreements of understanding (National University of Singapore, 1996). The second major academic player is Nanyang Technological University with research institutes like the Advanced Materials Research Centre and the Gintic Institute of Manufacturing Technology. Its strategic outlook of R&D activities exhibits an even more applied orientation, closer to the innovation segment of product improvement (Nanyang Technological University, 1996). This assessment holds also for Singapore's four Polytechnics, which are engaged in the promotion of R&D activities on a minor scale.

However, the problem of governing international co-operation in the restructuring towards a knowledge-based economy involves also skills formation in the provision of adequate manpower (Wong and Ng, 1997: 139). The most important skills development programmes are implemented by the Singapore Standards, Productivity and Innovation Board with a focus on the productivity and innovation performance of local small and medium-sized enterprises, whereas the Institute of Technical Education, established as an institution for secondary education and training, provides

training programmes that are co-organised by multinational enterprises (Singapore Standards, Productivity and Innovation Board, 2002; Institute of Technical Education, 2002). These efforts coincide with the assessment that a decisive area for future efforts in Singapore's innovation policy lies in the evolution of local technological capabilities, quite in accordance with the argument that East Asian development trajectories are generally in need of further impulses regarding R&D and product innovation, as they approach the technological frontier (Hobday, 1995: 200).

This situation is reflected by a low level of interaction between public research facilities and private enterprises, accompanied by a lack of networking interaction among local small and medium-sized enterprises (Wong, 1995: 34). Especially the integration of those small and medium-sized enterprises which do not belong to the high-tech segment of the private sector represents a persistent challenge (Wong, 1999: 281). However, even R&D collaborations between public research facilities and high-tech firms seem to provide opportunities for further improvement, not at least due to the specific R&D cultures that are associated with business and academia respectively (Phillips and Yeung, 2003). Yet in general, apart from these frictions within the high value-added domain of the Singaporean innovation system, it seems that spill-over effects from the knowledge-intensive industries to the comprehensive low-skill segment of small enterprises in the service sector need to be improved. Yet the underlying tendency of economic dualism actually reflects a common pattern in global cities and knowledge agglomerations, which contain a large proportion of low-wage and low-skills segments in their service sectors, set apart from a high-wage and high-skill segment (Sassen, 1994). At this point, the logic of technological globalisation with its combination of local specialisation and global flexibility needs to be complemented by integrative development strategies which seek a strengthening of structural cohesion in the local economy.

5. Conclusion

The Singaporean development trajectory has been supported by policies for maintaining locational competitiveness in terms of a continuous adaptation to the changing conditions of the world economy. These responsive policies have accounted for developmental opportunities which were offered by changes of the dominant techno-economic paradigm, recently highlighting the emergence of a knowledge-based economy with its exposed role for knowledge agglomerations in global cities. These agglomerations receive their structural impact as strategic hubs in the production and innovation networks of multinational enterprises. At this point, the interdependence of innovation policy and locational competitiveness becomes a factor of utmost importance. However, a major

problem is posed by the process of institution-building in support of the evolution of local technological capabilities. In this context, the Singapore government needs to harmonise its policies with the objectives of multinational enterprises; a situation which may include conflicting interests in various situations. In particular, the requirement of structural and institutional flexibility may conflict with an integrative development approach that supports the cohesion of the local economy. As indicated by the economic dualism of global cities and related high level agglomerations, balancing the integration in global innovation networks with the coherence of the local economy denotes a decisive challenge in promoting innovation-driven economic development.

Indeed, globalisation implies fundamental changes in the structuration of innovation systems. National systems of innovation were originally meant to represent a variant of specifically national systems of production, exhibiting national linkages in a systemic setting of interactions, whereas the innovation systems of knowledge agglomerations are linked with diverse networks of production and innovation within segmented layers of interaction that highlight the logic of locational competitiveness. Accordingly, institutional diversity and the corresponding level of complexity are considerably increasing. With the state remaining the decisive actor in charge of the institutional means for the support of economic development, the coordination of these diverse actors as well as the governance of the institutional complexity that coincides with their interactions is decisive for the design and implementation of innovation policies. The underlying spatial and institutional components are subject to a pattern of cumulative causation in which the strategic interventions of policy actors persistently shape competitive advantages. As indicated by the case of Singapore, the rationale of locational competitiveness thus denotes requirements of innovation policies facing the challenge of globalisation.

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