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A Place for R&D? The Singapore Science Park

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Summary. In the context of the globalisation of R&D activities, many urban and regional economies have attempted to create specific places in the hope of developing and embedding these activities. In this paper, it is argued that it is insufficient for such places to provide just physical infrastructure and investment benefits. Understanding actor-specific strategies and their enrolment in innovation networks and enabling institutional pre-conditions are equally important in embedding R&D activities. Based on a study of one such place—the Singapore Science Park—this paper explores the realities of science park formation. It is found that adequate institutional thickness and local embeddedness apply only to a small number of R&D firms in the Park. The paper also examines the myth that spatial proximity to R&D institutions and organisations automatically results in collaborative R&D efforts. The study shows that, for science parks to be more than a form of glorified property development, there is an urgent need for a fundamental transformation in the prevailing thinking of economic planning, R&D policies and urban development.

1. Introduction

The contemporary urban landscape in many advanced industrialised economies is often filled with property developments that aim to foster a relentless drive towards the informational and high-tech society. These projects of urban development focus on developing endogenous capacity in innovative activities through supporting high-tech start-up businesses and their research collaborations with relevant educational and public research institutions. In the context of the accelerated globalisation of research and development (R&D) activities during the past two decades (Cantwell, 1995; 1998; Simon, 1995; Dicken, 1998; Pearce, 1999), many such projects also cater to grounding transnational flows of R&D investments orchestrated by global corporations to tap into wider pools of specialised resources and to share costs that are attractively accessible in different cities and regions.[1]

In the urban studies literature, such property developments have a plethora of names, including enterprise zones, business parks, technology parks, research parks, innovation parks and science parks. In this paper, science parks are of particular interest because of their explicit aims to foster the develop-

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ment of innovative new companies and their R&D activities in an urban setting.[2] The definitions of science parks are elusive as there are a variety of terms used by different authors and organisations. For example, Massey *et al.* (1992, p. 14) noted that the UK Science Park Association (UKSPA) defines science parks as initiatives that

—have formal operational links with a university;
—encourage on-site formation and growth of knowledge-based businesses; and
—manage the transfer of technology and business skills to on-site businesses.

Some organisations prefer a more functional but open-ended definition. Defined by the Singapore Science Council (1987)—the predecessor of the National Science and Technology Board—a science park should have the objective of accommodating wholly R&D-oriented organisations and operations whose activities and/or manufacture of technology include a substantial amount of R&D. By neither defining what is meant by "accommodating" nor what are "substantial amounts of R&D", this kind of statement gives much leeway for planners to manipulate.

One major problem confronting the analysis of science parks as a place for innovative activities, however, is the question of spatial scale. Some authors refer science parks to the construction of cities (for example, Inkster, 1991), while others situate science parks in regions or clusters or corridors (for example, Broadbent, 1989). Still, some recent literature considers learning and innovation as a multiscalar process that go beyond a singular scale of analysis (Bunnell and Coe, 2001; MacKinnon *et al.*, 2002). For example, technopoles, described by Castells and Hall (1994) as a form of planned development of "innovation milieux", can be divided into three types of development at different spatial scales: regional industrial complexes of high technology firms (such as Silicon Valley); science cities that are strictly research complexes (such as the creation of Taedok in South Korea); and, intraurban technology parks that are deliberately created to establish high-tech businesses resulting from government or university-related initiatives. In this paper, the intraurban scale is used such that a science park refers to an urban property development with explicit aims to provide an amenable physical place for the commercialisation of new ideas and knowledge resulting from R&D activities. Put simply, a science park is meant to be a place for R&D within an urban context.

Curiously, policy and academic interest in science parks has declined somewhat in the 1990s, partly because the broader urban and regional structures in which science parks are embedded are recognised as far more important determinants of local economic development (Gertler *et al.*, 2000; Bunnell and Coe, 2001; see also Hudson, 1999; Sternberg and Arndt, 2001). By the same token, the urban governance literature has moved beyond place-specific hegemonic projects to investigate the rescaling of broader political and institutional structures (Harvey, 1989; Goodwin and Painter, 1996; Brenner, 1999; MacLeod and Goodwin, 1999; MacLeod, 2001). This research into the nature and extent of R&D activities in the Singapore Science Park, however, offers two potentially important insights into the role of spatial scale and the effectiveness of state-driven initiatives in high-tech development. First, the fact that Singapore is simultaneously a nation-state (national scale) and a global city (urban scale) with a territorial size of about 647 sq km points to a highly exceptional case in our understanding of science parks as a property development embedded in broader urban and regional structures. Conceived in scalar terms, the Singapore Science Park epitomises the national/urban drive towards excellence in research and technology, the commercial interest of a particular government-linked property developer and the R&D activities of tenant firms (foreign and local). This juxtaposition of different spatial scales (national-urban-developer-firms) in the production and evolution of the Singapore Science Park allows for an analysis of the complex interplay between national/urban economic policies and firm-specific strategies in (dis)enabling the role of science parks as a place for R&D activities. In this sense, one might expect significant differences in the pattern of innovative R&D activities between the Singapore Science Park and other science parks elsewhere that are embedded in wider regional innovation systems. For example, given the focal role of the Park in Singapore's national science and technology plan, one would expect high levels of localised interaction among tenants, high intensity of R&D activities and significant synergies through spatial proximity.

Secondly, unlike its counterparts elsewhere in industrialised economies, the Singapore Science Park represents a deliberate and state-driven attempt to attract the location of R&D activities by global corporations (Laffitte, 1985; Wong, 1995; Goh, 1998). Aiming to create specific places for capturing globalising R&D activities, the Singapore government has contributed to the Park's formation through various initiatives to generate agglomeration economies for R&D activities (for example, superior physical infrastructure, generous financial incentives and the nearby location of universities and research institutes). These initiatives are predicated on specific assumptions about the spatiality of innovation inherent in the science park model: that R&D activities typically cluster in geographically favourable locations; that there should be spatial contiguity or closeness between those elements of the innovation process located in the science park and the academe; and, that major production facilities should not be located in the Park. One would imagine that such agglomeration economies and cluster advantages might be better enhanced through deliberate government policies at the national scale, as evident in Singapore's relative success in industrialising the nation (see Rodan, 1989; Chiu *et al*., 1997; Perry *et al*., 1997; Low, 1998). There is, however, now increasing recognition in the literature that the empirical coincidence of universities and high-technology industry does not necessarily imply dense patterns of linkage (see Sternberg, 1999; Gertler *et al*., 2000). Saxenian critically noted that

> Spatial clustering alone does not create mutually beneficial interdependencies. An individual system may be geographically agglomerated, and yet have limited capacity for adaptation. This is overwhelmingly a function of organisational structure, not of technology, or firm size (Saxenian, 1994, p. 161).

In their extensive study of UK science parks during the 1980s and the 1990s, Massey *et al*. (1992, p. 42) observed "a strong warehousing and sales orientation" of those alleged R&D firms in science parks. Some establishments were essentially "marketing units" and others merely "marketed bought-in hardware and software with minimal modification by the park firm". One park company even admitted being "a commercial operation with no innovation … effectively a sales' office". Not all establishments characterised themselves as "leading edge" and software-oriented firms tended to be mainstream producers of applications, rather than those being involved in the R&D of software.

In Singapore, most policy research into science parks takes them as examples of learning experiences and therefore runs the danger of treating firms and actors as passive entities responding positively to the planners of these places (for example, Wang, 1994; Wong, 1995; Ang and Teo, 1997). Some of these studies take a policy-evaluation viewpoint to prescribe 'essential ingredients' for a science park. They sometimes reveal conflicting results, again reflecting the different possibilities of a park. For example, Muthusamy (1988) shows how tenants in Singapore place more emphasis on the financial and social environment. In contrast, tenants in UK science parks place more emphasis on such abstract attributes as prestige. Yong (1984) traces the locational factors that attract tenants to the Singapore Park and notes that having an intellectual base and a nucleus of scientific activity are more important than the aesthetic appeal or support services of a park. Others are interested in mathematically formulating its property management (Lim, 1995) or the role of marketing in creating demand for R&D spaces within it (Chin, 1991; Phua, 1993). One common problem in these studies is their assumption that with some pre-determined factors, R&D activities in the Singapore Science Park could be enhanced and the Park would succeed.

This exploratory paper aims to explain the nature and extent of R&D activities among tenants in the Singapore Science Park and to evaluate these activities in relation to the 'innovative milieu' of the Park. While the Park and tenant firms are taken as the main unit/scale of analysis, this is not without cognisance of the multiscalar processes and networks in which the Park and its tenants are embedded. Based on an analysis of empirical results from corporate surveys and interviews with tenants in the Singapore Science Park[3], it is argued that the evidence does not fully support the popular myth of the science park model that the synergies of R&D culture in a place will certainly rise up with a suitable location and an impressive property development, peppered with thick institutions and benefits and incentives. The empirical findings show that, even though the Singapore Science Park fulfils many of these positive criteria, the extent of R&D activities and collaboration among tenant firms tends to be relatively low. Their embeddedness in the institutional fabric of the Park is also rather shallow. These findings reflect the Park as little more than a form of glorified property development in one of the most outward-oriented global cities. More importantly, they show the urgent need to go beyond science-park-specific (local) factors in assessing the R&D activities of tenant firms because a narrow focus on these factors and conditions *within* such localised territorial ensembles as science parks tends to overlook the broader linkages and interrelationships cross-cutting different spatial scales of R&D activities. To place science parks within their appropriate "spaces of innovation" (Bunnell and Coe, 2001, p. 577), it is necessary to explore the non-local/decentralised networks through which actors such as tenant firms engage in R&D activities with other firms elsewhere (see, for example, the case of Taiwan's Hsinchu High Tech Park in Hsu and Saxenian, 2000; Saxenian and Hsu, 2001). These non-local innovation networks may explain the relatively low level of R&D activities in the Singapore Science Park. In this way, place may be conceptualised as a "product of the networks, interactions, juxtapositions and articulations of the myriad of connections" through which "social phenomena are lived out" (Allen *et al.*, 1998, p. 50).

This paper is organised into four main sections. The next section highlights the theoretical foundations of the study. After a brief discussion of the origin of the Singapore Science Park, the nature of R&D activities among firms in the Singapore Science Park are investigated. The penultimate section discusses the relevance of institutional thickness and local embeddedness in promoting the Park and sheds light on the relationship between spatial proximity and firm synergies. The concluding section discusses some implications of the findings for R&D planning and policy.

2. Unpacking Science Parks as a Place for R&D Activities

To understand why science parks are conceived by their planners and advocates as a place for R&D activities, it is necessary to unpack the different 'logics' and rationality of actors participating in their formation and the complex interaction among these actors. This analytical focus on science parks does not necessarily imply a theoretical departure from the multiscalar conceptualisation of innovative activities. Rather, through the analytical lens of science parks, it may be possible to appreciate better the ways in which spatial scales matter in the construction and promotion of innovative activities. Figure 1 presents such a theoretical framework to analyse the formation of science parks in relation to actors and processes operating at different spatial scales. To begin,

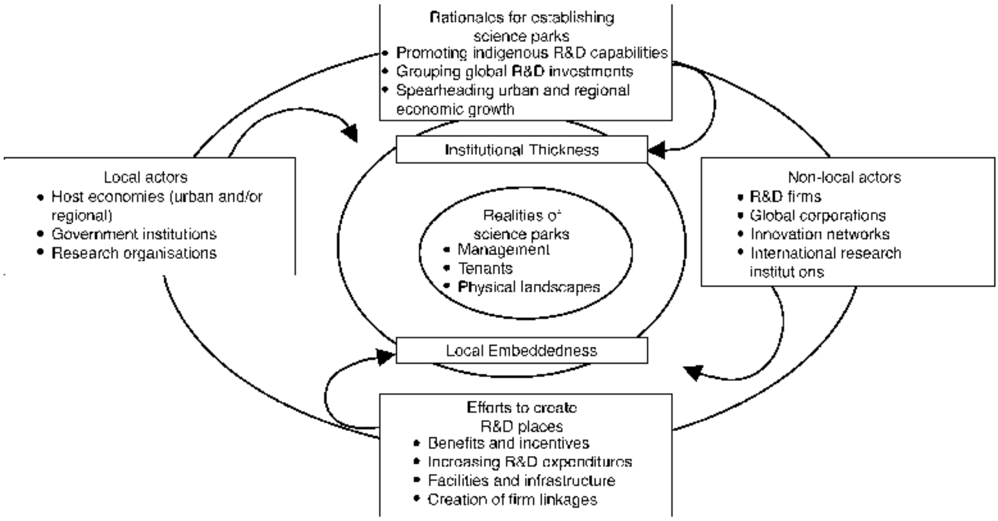

Figure 1. A theoretical framework for analysing science park formation.

science parks are conceptualised as spatially delimited *places* for R&D activities. The framework shows the binding forces that enable such actors as firms, research scientists and engineers (RSEs), and other institutions to coalesce in specific territorial ensembles known as science parks. Two major groups of actors are recognised, together with their strategic rationality and efforts.

Non-local actors refer to various cross-national or even global stakeholders who will potentially benefit from science park formation in different urban and regional economies: R&D firms, global corporations, innovation networks and international research institutions. These actors have access to strategic resources and assets that cross-cut differentiated networks at various spatial scales. Successful global corporations, for example, are capable of taking advantage of their home-country characteristics (such as technological sophistication, abundant capital, corporate governance and supplier networks) and blending their local operations to exploit host-ountry variations in local knowledge, business networks and so on (see Barlett and Ghoshal, 1989; Dicken *et al.*, 1994; Nohria and Ghoshal, 1997; Doremus *et al.*, 1998). These non-local actors are interested in science park formation insofar as these parks facilitate their extra-local R&D activities and other strategic imperatives (such as marketing and information-gathering initiatives).

Local actors, on the other hand, vary with the specific science parks in question. Generally, they comprise firms in the host urban and/or regional economies, government institutions and research organisations. These actors are 'local' to the extent that they have the resources and institutional will to participate directly in the creation of science parks as a place for R&D activities. These resources and institutions are often locally dependent because of their embeddedness in localised norms, conventions, practices and rules (see Cox and Mair, 1998; Cox, 1988). These localised relations, in turn, determine their *rationales* and *efforts* to create R&D places (represented in Figure 1 by the circular lines connecting local actors with their rationales and efforts). To government agencies and research institutions, science parks are often rationalised as a critical physical setting to promote indigenous R&D capabilities and to spearhead urban and regional economic growth. Early conceptualisations of innovation diffusion and growth-pole theory point to a direct relationship between R&D activities and regional development

(Higgins and Savole, 1987). Recent economic theories of agglomeration and clustering advantages explain why clusters are economically advantageous (Porter, 1990; 1998; Ellison and Glaeser, 1999). In many economies, the establishment of R&D places precedes an understanding of agglomeration and clustering dynamics. The rationales for attracting potential tenants in places vary, but they mostly relate to the advantages of cost savings, convenience, proximity to markets and suppliers, and the sharing of information (Westhead and Batstone, 1998).

The combined effects of sharing information, technology and facilities within specific territorial ensembles lend weight to theories on regional development—the development of places with specific functions (Storper, 1997; Cooke and Morgan, 1998; Scott, 1998; see also MacKinnon *et al.*, 2002). More specifically, many scholars have highlighted the emerging role of technology that, together with capital, spearheads regional development (Gertler, 1987; Castells, 1989; Castells and Hall, 1994; Erickson, 1994). According to them, technology plays a self-reinforcing role in developing regions that respond to the rise of the informational economy. The idea of planning and developing science parks has strong underpinnings in this technology-driven view of urban and regional development. Aptly called 'technopoles' that are justified by growth-pole theories of urban and regional development, Castells (1996, p. 10) argued that the "processes of formation of innovation industrial milieux" might lead to a "truly dynamic regional or economic growth". The prevalence and location of the physical place may be accounted for by this kind of economic theory. But the theory only explains why these places exist; it does little to explain how and why they develop and evolve over time.

To elucidate further the complex formation of science parks, it is necessary to recognise different layers of *institutional thickness* and *embeddedness* through which such local and non-local actors as firms and institutions mediate their strategic goals and rationality in specific places (see also Yeung, 2000; Amin, 2001; Jessop, 2001; MacLeod, 2001). Referring to Figure 1, at the centre of interactions that mediate the realities of a science park are the twin concepts of institutional thickness and local embeddedness. Institutional thickness, according to Amin and Thrift (1994, pp. 14–15), may be broadly interpreted in four dimensions: a strong, obvious institutional presence; high levels of interaction amongst institutions in a local area; development of sharply defined structures of interaction and coalition; and, mutual awareness of being involved in a common enterprise. Despite its original application to the regional scale of analysis, the concept 'institutional thickness' can be utilised to explain science park formation. This is because science parks are embedded within the broader urban and regional institutional structures (and, in Singapore's case, the national institutional structure). Figure 1 highlights the role of local actors in contributing to the institutional thickness of particular science parks. Collectively, they work together to create an institutional context that may appear to be 'thick' and beneficial to both local and non-local actors (such as R&D firms) so that they choose to locate their R&D facilities and activities in the park. In this sense, institutional thickness may contribute to the territorialisation of firm activities (see Dicken *et al.*, 1994; Dicken and Malmberg, 2001).

Although institutional thickness may capture the character of local agglomerations, Amin and Thrift (1994, p. 17) argued that there is a need to "problematise the relationship between institutional thickness and economic development" because of its "uneven geography of local development prospects and possibilities". Further to problematise this relationship is to introduce the idea of *embeddedness* within a place. Drawing upon Polanyi's (1944) work, Granovetter argues that

> the behaviour [of firms] and institutions to be analyzed are so constrained by ongoing social relations that to construe them as

> independent is a grievous misunderstanding (Granovetter, 1985, p. 482).

The argument here is that institutional thickness does not necessarily ensure the local embeddedness of R&D firms (local and non-local). In Figure 1, economic institutions (such as R&D firms) are conceived as embedded in wider social relations such that they are spatially bound by these relations in their locational and organisational strategies, as well as constrained by the influence of proximity in their R&D activities. Understanding their economic geographies requires more than an analysis of economic and locational factors. More importantly, it requires an examination of the complex ways through which these economic institutions are entangled in webs of social relationships and business networks that may cross-cut different spatial scales and reach. Hence, these economic institutions are conceptualised not as merely economic machines responding to external market and cost conditions (see also Tomer, 1998), but rather as social constructions by individuals "whose action is both facilitated and constrained by the structure and resources available in the social networks in which they are embedded" (Granovetter, 1991, p. 78).

For these theoretical reasons, the present authors believe that there is a need to understand tenants' relationships and linkages in R&D places, as these have a significant impact on their R&D tendencies and propensities (see also Turok, 1993; Leung and Wu, 1995; Jasinski, 1997; Pavlínek and Smith, 1997; Pearce, 1999; Lyons, 2000). Following Zukin and DiMaggio (1990), it is recognised that actors are involved in the mediation of embeddedness as institutions of collective bargaining, policies, social balance and employees' willingness to tolerate change. Similarly, Dicken and Thrift (1992, p. 289) have emphasised the "profound influences" transmitted by corporate organisations through their networks of "intra- and inter-firm transactional relationships". In Figure 1, R&D firms and/or global corporations are conceptualised as integral to the formation of science parks, whether these firms/corporations are 'domestic' or 'foreign' to the science parks concerned. As non-local actors, these firms/corporations interact within the same place-setting with other local actors—namely, the host economy (urban and/or regional) and other tenants in the park. Here, both actors *and* places (dis)enable R&D activities as the result of their dynamic interactions through the operations of norms and conventions—infamously known as "untraded interdependencies" after Storper (1997). Places that support R&D activities are in effect deliberately created localities to anchor global flows of R&D investment. This is exactly the kind of science park that Singapore seems to be creating—one that establishes and promotes high-tech societies as described by Castells and Hall (1994).

If, in the case of some science parks, places are deliberately constructed to develop and anchor R&D activities (for example, special R&D facilities), it would seem that the ability to construct and mediate realities is very much dependent on the degree of institutional thickness and local embeddedness. The host economy and institutions may use a variety of means to embed these tenants and in turn to create a favourable place for R&D activities. In Figure 1, benefits and incentives, facilities and infrastructures, and firm linkages are conceived as potential mechanisms to embed R&D firms in specific science parks. Ultimately, however, what determines the precise activities of tenants in a science park may go beyond their embeddedness in the park. This paper examines the assertion that embedded tenants enable R&D activity. It is argued that the decision by tenant firms to increase R&D activities often lies beyond the scope of the host urban/regional economy, a reflection of the non-local linkages in which these firms are involved. There is thus no necessary *a priori* relationship between a tenant's decision to locate in a science park and his/her willing or even capability to conduct R&D activities. Tenant firms can be attracted to science parks for a variety of reasons that may not have anything to do with R&D intention and activities.

Hence such terms as 'institutional flexibility', 'path dependency' and 'resistance' are possible outcomes of these problematic relationships (Dicken and Thrift, 1992). It is these dynamic relationships among firms, institutions and physical landscapes within place-bound contexts that form the key issues in the following empirical sections.

3. Creating R&D Places: The Singapore Science Park

The Singapore Science Park is a specific state-driven exercise to bring R&D to Singapore. As a newly industrialised economy and dependent fast-follower of technology, Singapore has invested significantly in R&D since the 1980s (Wong, 1995; Goh, 1998). Its national expenditure on R&D has been increasing steadily from 0.54 per cent of GDP in 1984 to 1.47 per cent in 1997 and 1.89 per cent in 2000 (http://www.a-star.gov.sg; accessed in July 2002). Table 1 shows that Singapore's R&D activities during the 1985–95 period were not too far from those in industrialised economies. Heralding the 'Second Industrial Revolution' in Singapore (Rodan, 1989), the year 1979 saw the first sign of establishing a national R&D programme (*The Business Times* (Singapore), 8 June 1979). Singapore's state philosophy was simple and clear: to prepare a conducive R&D environment that will help Singapore to "maintain a competitive environment" in the light of increasing competition in the global economy (Ministry of Trade and Industry, 1991, p. 60). From its conception, the Singapore government duplicated the successfully tried-and-tested Singapore style of industrial estate development in Jurong

(1) the nature of R&D according to guidelines is development, or "mission-oriented" research (*The Straits Times*, 14 September 1992);
(2) the directives will be government-led; and
(3) there will be a heavy reliance on foreign R&D firms.

The establishment of such institutions as the National Science and Technology Board (NSTB) was meant to support R&D activities in Singapore.[4]

The National Technology Plan (NTP) in 1991 maps out a technology corridor along the south-western area of Singapore in line with the Strategic Economic Plan (Ministry of Trade and Industry, 1991). In Figure 2, the concept plan for a technology corridor has contributed to the spatial integration of science habitats, business parks and tertiary institutions. There is thus nothing coincidental about the location of the Singapore Science Park in this corridor. Figure 2 shows the links that the Park can share with tertiary institutions and other major research institutions, as it is located within a 1 km radius of the National University of Singapore, the National University Hospital and such research institutions as the Institute of Systems Science and the Institute of Molecular and Cell Biology. There is no doubt that the Park can potentially benefit from such geographical advantages as physical proximity and agglomeration economies. Funding for R&D has frequently increased, with the latest figures at S$2 billion annually for the 1996–2001 period, reflecting the Singapore's government commitment to R&D (*The Straits Times*, 22 July 1996).[5] In 1995, the NSTB targeted R&D expenditure to be at 2 per cent of Singapore's GDP, with the private sector accounting for the majority share (NSTB, 1991, p. 30). In 2000, gross expenditure on R&D (GERD) grew by 13.3 per cent, from S$2.66 billion to S$3.01 billion. The private sector accounted for 62.0 per cent of the total national GERD (http://www.a-star.gov.sg; accessed in July 2002). Furthermore, an elaborate plan to develop Singapore into an innovation hub was announced in early 1998 (*The Straits Times*, 8 January 1998). In the same year, the government released a plan to develop a S$5 billion science hub in the South Buona Vista area along the Ayer Rajah Expressway that lies at

Table 1. R&D activities in selected countries, ranked by R&D expenditures

Country	Expenditures on R&D as a percentage of GNP 1985–95	Number of RSEs per million people 1985–95	High—technology exports	
			$ millions	Percentage of manufactured exports
Sweden	3.4	3714	21 969	34
Japan	2.9	6309	152 431	38
Korea	2.8	2636	44 433	39
Finland	2.5	2812	8 797	26
US	2.5	3732	197 657	44
France	2.4	2584	68 655	31
UK	2.2	2417	95 755	41
Denmark	1.9	2647	8 174	27
Norway	1.8	3678	2 703	24
Australia	1.7	3166	6 415	1.7
Belgium	1.7	1814	—	—
Canada	1.6	2656	33 608	25
Italy	1.1	1325	32 747	15
Singapore	**1.1**	**2728**	**74 585**	**71**
India	0.8	149	2 654	11
Indonesia	0.8	—	4 474	20
South Africa	0.7	938	—	—
Brazil	0.6	168	5 175	18
China	0.5	350	33 344	21
Argentina	0.4	671	1 355	15
Malaysia	0.4	87	39 490	67
Mexico	0.4	213	29 692	33
Hong Kong (China)	0.3	98	7 392	29
Philippines	0.2	157	6 249	56
Thailand	0.1	119	17 758	43

Note: Not all countries are reflected in the table here as there are more than 250 countries in the original source.

Source: http://www.statistics.com; accessed in July 2002.

the lower right-hand area within the technology corridor shaded in Figure 2 (*The Straits Times*, 16 September 1998). It will be a place where "ideas born within a scientific community are cradled, nurtured and developed into commercial products", creating a "focal point for R&D and developing an innovative milieu" (*The Straits Times*, 16 August 1998).

In this national context of promoting research and innovation, the Singapore Science Park was set up in 1980 as a place where R&D can converge and create synergies with institutions and firms alike, and researchers can work anytime, meet and share ideas.[6] The Park's establishment can be read as the "first positive indication" of the government's recognition of linking R&D activities to its economic policy (Goh, 1998, p. 60). The Economic Development Board (EDB) and the Jurong Town Corporation (JTC), both national economic institutions spearheading economic development since the 1960s, were directly involved in the planning and creation process of the Singapore Science Park. According to the former managing director of Arcasia,[7] the Park was literally a brainchild of the former chairman of the Jurong Town Corporation

> Before the 1980s, there was very little research job being done in Singapore. Singapore was basically a production base. At that time, the Government realised that Singapore cannot just depend on production. Production requires low cost in order to be attractive and hence R&D was

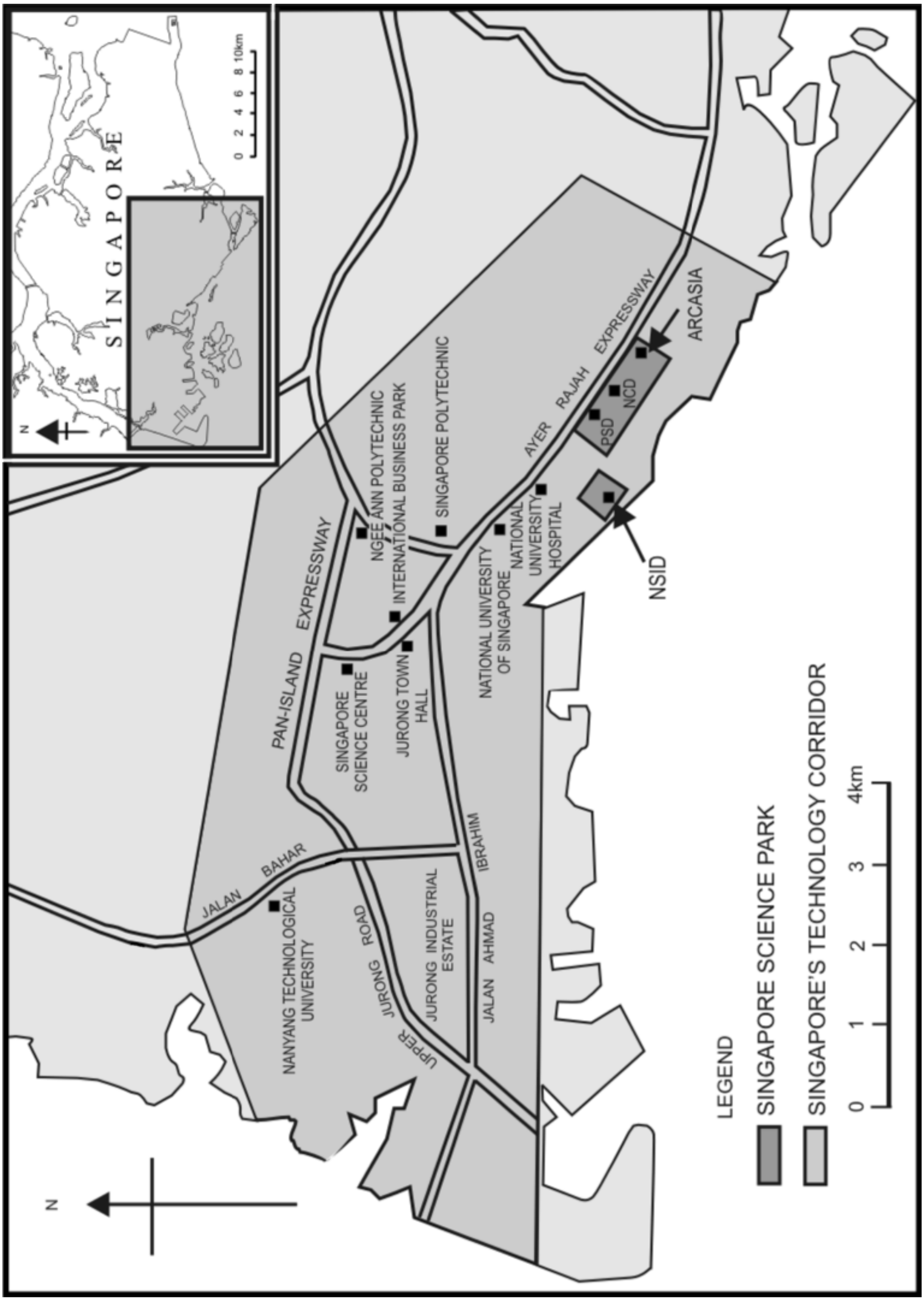

Figure 2. The location of Singapore's Science Park and Technology Corridor.

> introduced into the Singapore environment. There was no venture capitalist at the time doing R&D when we started. There was no budget even in the then National Science Council to carry out R&D work. There were only a few people running it. EDB and JTC were contemplating about this idea of R&D. The then Chairman of JTC found that the opportunity to get some attention on Science Parks is very great. Out of the blue, he sold the idea of Science Park without going through the proper channels. He was taking a risk. To him, you should strike the iron while it is still hot. It was around 1981 and 1982. He said it should be located near to the National University of Singapore. We then have to look for the land in order to develop. At that time, this piece of land was occupied by the Army. Due to the good publicity, the entire process got started. In the shortest possible time, we managed to get the Army to vacate. We then set up this Science Park after going overseas to look at about 10 science parks (interview; 16 December 1998).

The Jurong Town Corporation continued to manage the Park until the incorporation of Arcasia in 1990. The advantage of transferring the Park's management to its subsidiary is that Arcasia offers "the flexibility, in terms of ease of changing policies and coming up with innovative products. Government agencies can change things but at a slower pace. We also wish to subject ourselves to more private sector's disciplines" (former managing director of Arcasia; interview, 16 December 1998).

However, this idea of a science park in Singapore received mixed reactions. Initially at its first mention in the early 1980s (again when the NSTB announced its National Technology Plan in 1991 and recently, with the current debate on nurturing technopreneurship; see Coe and Kelly, 2000, 2002), there were many arguments for and against the formation of the Singapore Science Park and the Science Hub (see *The Business Times*, 16 April 1984; *The Straits Times*, 27 August 1980, 25 May 1990, 17 September 1998, 23 September 1998). These arguments ranged from poor public perception, to a lack of critical mass in RSE, a total transformation of the education system and a change in attitude towards failure, risk-taking and creativity. The general thread was that Singapore is not ready to move towards a knowledge-based economy. One response highlighted the pitfalls on efforts to become the Silicon Valley of the East as it misses out the very spirit of entrepreneurship

> It would be a mistake to expect a certain output of high-tech entrepreneurs in a predicable, mechanistic manner, just because there has been so much investment, facilities and people put into the effort. The long-term consequence … is that this nation will be far less directed by the government and more market-driven (quoted in *The Straits Times*, 29 December 1998).

A report by the Political Risk and Economic Consultancy based in Hong Kong, contrasting Taiwan's environment to Singapore's, concluded that although Singapore has better technological infrastructure, Taiwan is more tolerant of failure and has a vibrant entrepreneurial atmosphere. The report went on to criticise Singapore's openness to new technology as "big on substance but short on flair". Although a "master at creating and maintaining very high quality infrastructure", Singapore is finding it "very difficult to nurture the sort of vibrant, freewheeling atmosphere necessary to transform the country into a centre for technological innovations" (Quoted in *The Straits Times,* 13 October 1989).

More than two decades since its inception, the 65-hectare Park (I, II and III) now claims to house more than 200 institutions registered as 'research facilities' (307 companies in total in 2000; http://www.sciencepark.com.sg, accessed in July 2002). Comprising both local and non-local actors as conceptualised in Figure 1, the tenants constitute the biggest and most influential group of actors involved in the production of Singapore's R&D activities. The Park's tenants include such global players as Sony, Exxon Chemical, Silicon Graphics and Lucent Technologies, as well as small and medium enterprises (SMEs) and start-ups. Local R&D facilitators, such as the Productivity and Standards Board (PSB) and the Infocomm Development Authority (IDA) make up the second group of diverse, but active, actors in the Park. The function of these organisations is to support R&D activities in the Park and in Singapore. The Economic Development Board provides R&D benefits and incentives to the Park's tenants, while the NSTB encourages all R&D activities in Singapore. Arcasia is responsible for the Park's overall property development, marketing and management (amongst other industrial and business parks in Singapore). The National Technology Plan identifies seven main R&D areas: information technology (IT), manufacturing and engineering technology, pharmaceuticals, telecommunications, chemicals, electronics and, lately, the life sciences (http://www.sciencepark.com.sg; accessed in July 2002). The differentiated ability of these groups of actors to mediate their strategic goals and objectives results in a production of the Park as an R&D place that may not resemble its original intended role and functions. The next section examines in greater detail the nature of R&D activities among actors in the Park.

4. The Nature of R&D in the Singapore Science Park

4.1 Factors for Locating in the Singapore Science Park

The industrial distribution of the 166 tenants in the Park is indicated in Table 2. The national push for an 'information-based economy' explains why the population comprises a significant number of IT firms. About 50 per cent of the tenants are foreign firms. In terms of their origins, 27 per cent are American, 11 per cent are European, 9 per cent are Japanese and 3 per cent come from other countries. Most local firms are small and medium enterprises (70 per cent); 23 per cent are start-ups; and the rest are research institutes.[8] From the survey, the average size of firms in the Park is between 5 and 30 staff. The average duration in the Park is 6 years. These variables can, to a certain extent, explain the nature of R&D activities by the Park's tenants. General guidelines provided by the Park's management are insufficient to ensure that tenants conduct a substantial amount of R&D work. Some of these guidelines require tenants: to be involved in some R&D work; to have an R&D manpower profile; and, to incur a proportion of R&D expenditure. The admission criteria for tenants, nevertheless, are very flexible. For example, tenants are not required to have a high R&D profile to be accepted by the Park. According to Arcasia's spokesperson, tenants who can justify their ability to "add catalytic value to other tenants" are also considered. Although Arcasia is not the watchdog for non-performing R&D firms, it is not surprising to find firms that get by through a variety of R&D work such as testing and inspection services, or by providing technical support to their parent firms (mostly located outside Singapore).

Table 3 summarises the reasons cited by tenants for choosing to locate in the Park. Two key findings emerge. First, the spatial proximity rationale does not seem to appeal to many tenants located in the Park. The reasons for locating in the Park are based more on such science park perks as 'image' and 'infrastructure', rather than on government incentives for the cluster rationale. 'Attractive infrastructure and support services' has the highest response at 33.3 per cent, followed far behind by such reasons as 'invited to establish in the park' (12.8 per cent), 'convenient location' (12.8 per cent) and 'close to similar activities' (12.8 per cent). None felt that the 'links with suppliers and industries' was an important consideration for establishing themselves in the Park. Secondly, when asked what aspects of the science park they liked best, most respondents chose 'facilities' and 'physical landscapes'.

Table 2. Profile of firms in the Survey and Tenant Directory, 2000

	Survey sample firms			All firms in the Tenant Directory	
Nature of industry	Local	Foreign	Total (percentage)	Total	Percentage
Information technology	6	2	8 (24)	72	43.4
Chemicals	1	4	5 (15)	19	11.4
Telecommunications	2	2	4 (12)	10	6.0
Engineering	1	2	3 (8.7)	16	9.6
Food/Flavours	0	3	3 (8.7)	7	4.3
Life sciences	1	2	3 (8.7)	6	3.6
Pharmaceuticals	2	1	3 (8.7)	5	3.0
Others	1	2	3 (8.7)	14	8.4
Electronics	1	1	2 (5.8)	17	10.3
Total	15	19	34 (100)	166	100

Sources: Tenant directory (http://www.sciencepark.com.sg; accessed in January 2000) and authors' survey.

These responses imply that the Park has only been successful in appealing to tenants who are attracted to the image of the Park, but not its functioning aspects (such as research links and collaboration). The efforts by local actors to create an attractive physical place (see Figure 1) seem to be realised, although the exact tenants may not be what they had in mind. This unintended outcome may be explained by the overt focus of the planners and developer on the physical aspects of other science parks they visited before building the Singapore Science Park. As the former managing director of Arcasia explained

> At the beginning, we were very fresh and did not focus on the research part. We were focusing on the real estate development part of it. We were more concerned with the looks of the building, the landscape, the types of finishes that they [other science parks] used and the amenities that they had. Subsequently, those other people who took charge of the Science Park went deeper into the actual requirements and looked into providing more value-added services to the potential investors (interview; 16 December 1998).

4.2 Realities of R&D Activities in the Park

A recent report describes the Singapore Science Park's surroundings as "lush green to nurture the brainy with its oasis-like landscaping and diversions like movies" (*The Straits Times*, 24 July 1998). Apart from the serenity, the Park retains a "reclusive image" because of its "backwater remoteness" and the "stark, forbidding lines of its spaceship architecture". The Park's website even boasts that it is "South East Asia's most prestigious location for R&D" (http://www.sciencepark.com.sg, accessed in July 2002). The question is whether R&D is done, despite the impressive image of the Park. Based on findings from the survey, it is argued that *creating* a place for R&D is far less predictable than *providing* for it. To measure the nature of activities is challenging in a context where there are tremendous variations in industries and corresponding research and/or development processes. A systematic description of such variables include input indicators (proportion of R&D expenditure and number of RSEs) and output indicators (listing of major developments and number of patents). These indicators may offer some glimpses into the Park's activities, although the realities are far more complicated and less predictable than what is normally suggested in local newspapers or public speeches.

When asked to describe the main activity of their firm, 12 respondents (35 per cent) indicated R&D, another 6 (18 per cent) indi-

Table 3. Reasons for tenants' location in the Singapore Science Park

		Responses	
Category	Factors	Number	Percentage
Science Park perks	Attractive infrastructure and support services	26	33.3
	Supportive management	3	3.8
	Lower costs	4	5.1
	Total	33	42
Government benefits and incentives	Invited to establish in park	7	9.0
	Supportive government policies	7	9.0
	Total	17	30
Spatial proximity	Close to market/demand	3	3.8
	Convenient location	10	12.8
	Links with suppliers and industries	0	0
	Total	23	28
Total		70	100

Notes: Firms were allowed to choose more than one option. All percentages are rounded off.
Source: Authors' survey.

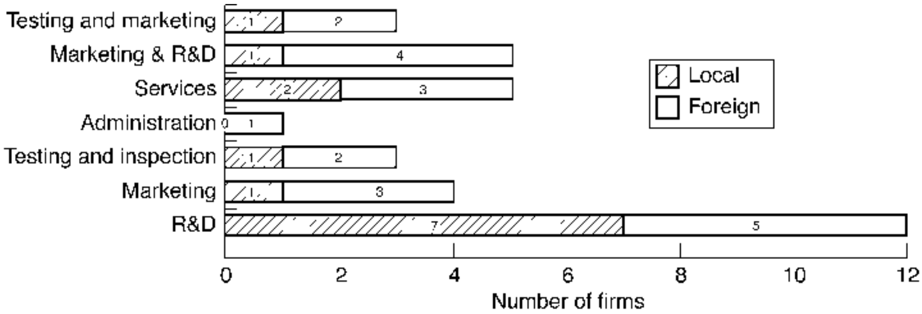

Figure 3. Summary of tenant firms' main activities. *Source*: Authors' survey.

cated 'marketing and sales and R&D'. This results in a total of 18 firms (53 per cent) that considered R&D to be their main activity (see Figure 3). There are tenant firms that are actively involved in R&D activities and those that are not. A total of 16 (47 per cent) firms indicated no R&D activities and 11 (69 per cent) of them are foreign firms. One small food/flavours Japanese local sales office replied that "There is only my boss and myself. R&D is done in Japan. Over here, we sell the R&D products". A Japanese electronics firm, with a rather large presence in the Park (in terms of office space), only devotes a proportion of its activities to R&D. The majority of its activities are to provide "software and support services" to their company in Japan.[9] This finding confirms the findings of other studies of Japanese electronics and computer firms—that they tend to have closer relationships with their parent firms than with the host economy. Their R&D activities are either to duplicate their parent companies or to localise products (Florida and Kenney, 1994; Angel and Savage, 1996). If so, this implies that Japanese firms (that make up 9 per cent of all tenants in the Park) would contribute less significantly to groundbreaking R&D activities in the Park. Revisiting Figure 1, it is suggested that the non-local innovative networks in which foreign subsidiaries in various locations play different functional and strategic roles largely determine the nature and extent of their R&D activities in the Park. These non-local strategic influences, measured in what might be termed 'relational proximity' (Amin and Cohendet, 1999), are perhaps more significant than local conditions and physical proximity in shaping the sort of R&D activities in the Park. This empirical finding certainly resonates well with Bunnell and Coe's suggestion that

> Shifting the focus of research towards social networks between appropriate people and groups, in turn embedded in particular places, may improve our understanding of innovation processes in a way that territorially restricted studies cannot (Bunnell and Coe, 2001, p. 578).

A seemingly encouraging number of firms described their main activity to be R&D (Figure 3). But they are involved in various types of R&D activities. Results from both the surveys and interviews indicate that the nature of R&D activities ranges from mostly applied R&D activities to the organisation of these activities. In Table 4, 14 firms out of 34 (42.1 per cent) described a total of 34 major developments. These 14 firms have spent an average of 7.3 years in the Park. These developments tend to be new products ($n = 10$ or 71.4 per cent) and fewer are new and improved processes ($n = 4$, or 28.5 per cent). Only 8 (23 per cent) out of 25 are patented. A large number of these firms spent above 75 per cent of their total expenditure on R&D activities. This tentatively implies a positive relationship between R&D expenditure and R&D developments.

Table 4. Comparison of local and foreign firms by proportion of R&D expenditure

		Percentage of expenditure on R&D		
Type of firms	With major R&D developments	Above 75	50–74	Below 50
Local firms (Percentage)	8 ($N = 15$) (33.3)	5	2	1
Foreign firms (Percentage)	6 ($N = 19$) (40)	3	3	1
Total (Percentage)	14 ($N = 34$) (42.1)	8 ($N = 14$) (57)	4 ($N = 14$) (29)	2 ($N = 14$) (14)

Notes: Total number of foreign firms in the survey = 19; total number of local firms in the survey = 15.
Source: Authors' survey.

From the in-depth interviews, however, it seems that there are other kinds of R&D activities by tenants in the Park. One respondent from a pharmaceutical start-up described their activity as the "organisation of clinical research and testing drugs to prove their effectiveness". In other words, they do the "software to prove the claims that the drugs work". The hardware—or the testing—is done in North Asia, while the office in Singapore provides the venue where they interact with clients. The main reason for the lack of R&D hardware in Singapore, the respondent explained, is that Singapore attracts pharmaceutical business headquarters, not R&D-based operations. Although the commercialisation of the pharmaceutical industry has taken off, the research community in Singapore remains small. This highlights an earlier concern about Singapore's need to achieve a critical mass in RSE to support R&D activities. This question of whether Singapore has enough researchers, according to Arcasia's marketing manager, is the most common and difficult one when it tries to secure new tenants (interviewed; 16 December 1998). In the IT industry, it is difficult to assess the nature of R&D activity because IT firms are only set up when there is product development. An IT SME described its activities as the development of ideas. Pure research occurred only when the director had an idea—that made him set up the firm.[10]

Among tenants that are actively involved in R&D, it is not an easy task to make research pay for itself. An example is research institutes. They make up a group of tenants who seem more embedded in the Park than other tenants because of their institutional origins as national research institutes (see Figure 1). One reason why these research institutes can be actively involved in R&D is that the Singapore government funds them. The 2 national research institutes interviewed have on average produced 6 major developments, received a number of benefits and employed more than 40 RSEs (interviews with marketing directors of research institutes, 28 February 2000). Although they are able to list a number of major developments, to make research pay for itself is still very demanding. Both research institutes have an average turnover of S$10–29 million, but their rising expenditure has forced them to balance expenditure and income. While the interviewees described their main activity to be R&D, the "more mundane chores" come in the form of providing testing and inspection services to private firms. This is quite a substantial proportion of their daily operations, but the income from these services "keeps them in the blue".

5. Embedding R&D Activities in Places?

The lack of significant R&D activities in the Singapore Science Park can be explained by the extent to which R&D firms are embedded, as conceptualised in Figure 1. It is argued that, despite concerted and often state-driven efforts to create an 'innovative milieu' in/around the Park (see section 3), the level of institutional thickness and local embeddedness remains low. This reality of the Park in turn reduces the possibilities for R&D firms (local and non-local) to reap the advantages of geographical clustering—synergies, the sharing of information and special links and relationships. To a large extent, the Park fails as a place for the agglomeration and enhancement of R&D activities. This section postulates that the relationships among actors (local and non-local) significantly affect their differential degrees of institutional thickness and local embeddedness.

5.1 The Role of Institutional Thickness

In a bid to promote R&D activities in the Park, many government-linked institutions were set up in the hope of establishing collaboration between local universities and industries. Despite their clearly defined structures, the relationships among these institutions are not always compatible and cohesive. For example, there is a gap between the NSTB, an organisation that promotes R&D activities in Singapore and Arcasia, the developer and manager of the Park. It seems to be more a matter of too sharply defined structures that result in a gap between the two organisations' responsibilities. The NSTB's responsibilities include providing, encouraging and supporting R&D. Arcasia's responsibilities include property development of technology parks in Singapore, and the provision and maintenance of physical infrastructure.[11] As one interviewee observed, the "musical chair arrangement" of the roles played by the NSTB and Arcasia throughout the years leaves an institutional void in that few firms (particularly foreign) are exactly sure to whom to turn for assistance.

SMEs and start-up firms particularly experience this problem. Beyond applying for benefits and incentives and maintenance of facilities, many firms are not sure which institutions to ask for assistance when they need to look for venture capitalists, patenting procedures, loans and clarification of such policies as labour issues. Others felt that, although there are meetings and annual surveys conducted by Arcasia, the organisation's laid-back approach contradicts promises made by the Singapore government—a sign of incompatibility between proactive state/national policies and the daily realities of the Park's management practices. As the result, some firms felt "disillusioned" with the way things are managed in the Park.[12] In the survey, the lack of government support was ranked as a major concern, only after the internal concern of 'rising costs of operations'. Interestingly, the lack of a supportive management is much less a concern for tenants (ranked second to last), simply because "they [Arcasia] take charge of the buildings, not us".[13]

The on-going debate between research institutions and the national university nearby is another example that indicates a rift in building institutional thickness through the mutual awareness of common goals. According to Hang (1999, p. 33), the former deputy director of the NSTB (now deputy chairman of A*Star) and deputy vice chancellor of the National University of Singapore, it is essential that research institutes serve as the training-ground for postgraduate research students. He added that an institute that only has a single dimension of industry collaboration is underutilising its vast resources. However, interviews with two research institutes suggest that there is a stark difference between their understanding of their respective roles and functions, as compared with those of the university. A respondent from a research institute explained

> We have had university staff come in here … They used our facilities freely and expected us to wait for them … What they didn't understand is that we are not here to serve them. We were set up for the industry (interview with a research institute's marketing director; 28 February 2000).

The physical presence of institutions does not necessarily imply 'thickness' (see also Amin and Thrift, 1994; Raco, 1998; Keeble *et al*., 1999). Although these research institutes engaged in a fair amount of R&D, synergies between research (pursued by the university) and development (pursued by research institutes) may be missing.

In a bid to woo tenants to the Park, a great amount of investment was made to provide an attractive environment through the provision of elaborate physical infrastructure and facilities. The cost of infrastructure development in the Singapore Science Park project was estimated to be S$750 million (*The Straits Times*, 10 January 1981) and the Singapore Science Park II cost another S$291 million (*The Straits Times*, 15 October 1993). These permanent facilities run at high cost regardless of use. As mentioned earlier, 26 firms (33.3 per cent) chose to locate in the park because of its attractive infrastructure. 'Facilities' were ranked as the top aspect that tenants like about the park (see Table 3). Firms that use expensive facilities tend to be involved in a greater amount of R&D and feel 'tied down' to the place. For example, the use of expensive machinery by research institutes in a way, explained one interviewee, binds them to R&D activities, and justifies the need to pursue marketable R&D in order to pay for their capital investment.

But there are also firms that occupy spaces in the Park irrelevant to their activities, as these spaces are meant for heavy R&D. The presence of such firms also implies that they do not feel a deep sense of local embeddedness because there is no real need for them to be in the Park. For example, a foreign software development firm has been located for 11 years in a building meant for heavy R&D. The firm, fortunately, does not see the need to move out simply because they feel 'comfortable'. But their continual expansion in a building constructed for heavy R&D aggravates the underutilisation of resources. There is also some leasing out to temporary tenants in these buildings equipped to handle heavy R&D activities (especially in Science Park I). One such tenant (the dean of a foreign business school) who was interviewed, explained their presence in the Park to be a "temporary one" until their new school is completed. The Park was chosen neither for its facilities nor for its R&D reputation. It was suitable because the school was close to the Park and the university. This business school currently takes up 5 units of office space in the Park, each of about 4000 square feet.

In addition, the attraction of infrastructure and facilities applies only to certain industries—namely, the engineering, electronics and telecommunications industries. On the other hand, the seven 'placeless' IT firms in the survey did not consider the Park's facilities attractive. It is highly unlikely that these IT firms—constituting a fair number of the Park's tenants in Table 2—would feel deeply embedded. The locational attraction of other R&D and non-R&D places, both within and outside Singapore, also decreases their local embeddedness in the Park. This is especially true for SMEs and foreign firms. For example, 20 out of the 34 (58.8 per cent) responding firms had considered other locations before deciding to locate in the Park. Out of these 20 firms, 14 of them (70 per cent) considered other commercial buildings within Singapore as alternatives. Based on their greater likelihood to consider other locations, SMEs are least likely to be embedded in the Park. The common reasons for considering other locations are high costs ($n = 12$ or 44.4 per cent) and location not ideal ($n = 9$ or 33.3 per cent). These firms tend to exhibit the spatial logic described by Yeung (1998, p. 229) as "territorial tendencies of capital" rather than the agglomeration tendencies of R&D or science parks.

Although there exist some good reasons that may make tenants stay (such as a good scientific image or prestigious address), two challenges remain for this kind of local embeddedness. First, it is possible to duplicate the Singapore Science Park image. Technology and business parks have been sprouting up all over the island. Consequently, the ability of the Singapore Science Park to retain its tenants remains in doubt. According to the Arcasia spokesperson, the management wishes to present to the world a premier address for R&D in south-east Asia. But this image is not easily achieved because what makes an address desirable is something intuitive and intangible (see Malaysia's ambitious attempt in the context of its Multimedia Super Corridor project; Bunnell, 2002). The only way for Arcasia is to satisfy the needs of existing tenants who coincidentally may not be very interested in conducting innovative R&D activities. The second issue relates back to the central theme of this paper—that is, the *provision for* R&D activities does not necessitate these activities. By the same token, a higher degree of local embeddedness does not equate with R&D activities. Out of the three tenants interviewed that will stay in the Park, one described the firm's main activity as the "organisation of R&D activity for the industry". The other admitted that it is "spending very little on R&D". The third, in a predicament, will have to stay, but does not seem to conduct a lot of R&D activities. Instead, it is the regional headquarters for technical services. This European firm indeed had problems looking for a suitable alternative location. No commercial buildings in Singapore would accept it because the food/flavours firm deals with flammable goods and emits odours during its testing process. But the Park was happy to oblige on the grounds that the parent company in Europe has a "high R&D culture" (interview; 18 February 2000)!

5.2 Synergies of Spatial Proximity

A true place for R&D activities needs a certain level of formal and informal synergies among tenants for the cross-fertilisation of ideas and knowledge. Synergies may be simply defined as the synthesis of different advantages to produce greater collaborative efforts. While it is problematic to determine how informal synergies can affect R&D activities, formal synergies in the form of project collaborations and linkages can be empirically measured (see also Gertler *et al.*, 2000; Sternberg and Arndt, 2001). There are many efforts to promote synergies in the Park, but the most obvious effort is to enhance its spatial proximity to nearby institutions and universities (see Figure 2). In fact, the nation-state of Singapore is small enough in size that spatial proximity exists throughout the entire island. Other large-scale efforts to promote synergies include letters of understanding between the government and institutions to promote R&D projects. There are also small efforts to create some synergies in the form of seminars and meetings organised by such institutions as Arcasia and the NSTB.

The general attitude towards spatial proximity as an effort to promote synergies is that it is neither very useful nor harmful. Table 3 has already shown that not many firms considered locational links as their prime reason for locating in the Park. Yet being close to similar firms does not constitute competition for the firms. Moreover, it is impossible to create spatial proximity for everyone in the Park due to their different needs. For example, four respondents considered other locations because they wanted to be "near activities not found in the Park". Revisiting the rift between research and academic institutes, one interviewee from a research institute explained why developing collaborative links with universities is often more a discursive ideal than a practical reality

> Having collaborations are good because it gives us a presence among a high intellectual community … [It's] bad in the sense that sometimes, we have to be differentiated between a research lab and a university … Universities are interested in exploring knowledge, but we are interested in developing products.

Similarly, another interviewee felt that there is a great difference between research and development arising from the competitive nature of industries

> After an idea has been proven within the academic world theoretically, to change it into something marketable is very differ-

Table 5. Collaborations among tenants in the Park

	R&D project developments	Product development	Testing and inspection
Number of firms (percentage)	22 (65)	15 (44.1)	18 (40.9)
Firms in Park			
Yes	13	4	9
No	9	11	9
Status			
On-going	5	9	12
Once only	17	6	6

Note: Total number of firms in survey = 34.
Source: Authors' survey.

ent. Being close to the university has problems. Some ask why we don't collaborate, despite being so close. The reason being we are different. We can do research projects, but they cannot do development projects. In the university, there cannot be such projects because of the competitive nature of industries … No one would pass around such knowledge to universities because one never knows where it will end up.

As a result, these research institutes would rather 'sell' their R&D capabilities by linking up with foreign firms than with local universities—more empirical evidence to support our claim that non-local innovative networks might be more important in determining the nature and extent of R&D activities in the Park. This directly contradicts the expectation that the institutional presence of universities will spur R&D activities in the Park. Synergies between academic and research institutions do not seem to piece together adequately the R&D puzzle, despite them being geographically next to one another.

Table 5 summarises the collaborative efforts among surveyed tenants. Of the 34 major developments described earlier, 29 were done in collaboration (85.2 per cent). An encouraging number of tenants ($n = 22$ or 65 per cent) have collaborated on R&D projects, but most have done so only on a one-off basis (17 out of 22 or 77.2 per cent). Collaborations occur quite equally among tenants within and outside the Park, highlighting the dilemma of R&D firms' strategic desires to be both locally embedded and globally linked (Patel and Pavitt, 1991; Tödtling, 1994; Patel, 1995; Perry and Tan, 1998). Ironically, despite these encouraging collaborative efforts, the survey shows that 'linkages with institutions' (31 out of 98 or 32 per cent) is the most agreed upon aspect of the Park that can be improved. This finding implies that there are tenants who wish to collaborate with institutions, but that opportunities have not yet arisen.

One final observation from tenants involved in collaborative projects is that only some enjoy substantial synergies. While there are tenants collaborating amicably, there are those that are unable to collaborate with anyone at all. The reasons vary very strongly according to the type of industry. Two out of the three pharmaceutical firms surveyed do not engage in any collaboration because there are no matching or relevant firms. In contrast, three out of the four food/flavours firms indicated some attempt at R&D collaboration. But these collaborations occur at the margins of significant R&D activities: they range from the supply of raw materials, to the use of facilities, to the testing of local flavours.[14]

6. Conclusion and Implications

This paper presents some empirical findings on the role of the Singapore Science Park as a place for R&D activities. First, there is a stark difference between firms that are actively involved in R&D and those that are not. Of those that are involved in R&D, most tend to focus on the 'development' aspect. There are positive relationships between some firm-specific variables (for example, size of RSEs and expenditure on R&D, duration of stay in the Park, and national origins) and major developments. Secondly, foreign (non-local) firms are most likely to be involved in a variety of activities other than R&D. This is consistent with other studies of foreign R&D activities in host economies (for example, Florida and Kenney, 1994; Angel and Savage, 1996; Gertler *et al.*, 2000). Foreign firms in the Park commonly described their activities as the localisation and organisation of R&D activities and the provision of R&D support. Data from in-depth interviews show that the presence of many interrelated institutions does not necessarily enhance the R&D activities of the Park's tenants. While the state and the Park's management have clearly put a lot of financial and physical resources into embedding R&D firms in the Park, the extent to which they have succeeded remains unclear. Factors that hinder local embedding of firms include the lack of carefully matched provision of infrastructure and firms' concerns with the rising cost of operations. Government-funded and invited firms/institutions seem the most embedded tenants in the Park. One potential embedding factor is the Park's scientific image and address. But the likelyhood of its being replicated in Singapore and elsewhere greatly reduces its potential for increasing local embeddedness. Moreover, embedding a firm does not automatically increase its level of R&D activities. Despite a large number of developments done in collaboration, improving linkages with institutions is the most-agreed-upon task for the Park's management. Spatial proximity is neither useful nor harmful to most firms. Being close together does not entail any potential competitive threat among tenants. As Castells and Hall (1994, p. 230) pointed out almost a decade ago, only a certain kind of university and a very specific set of linkages can create the "innovative milieu".

What then are the implications of this study for the understanding of R&D activities and the formation of science parks? First, the study supports the logic of approaching R&D in planned places as R&D businesses, but it does not end there. There needs to be an extensive and detailed application of business and research concepts in R&D. Some of these include the wider appreciation of the important role of actor networks (local and non-local) in promoting innovations and R&D activities. Creating places for R&D activities might not be very difficult from a host economy's point of view, since it often involves investment in physical infrastructure. Making these places really work *as* centres of innovation and R&D activities might be a totally different activity, entailing plugging these places strategically into innovation networks cross-cutting different spatial scales. From this point of view, developing R&D places such as science parks requires a lot of 'strategic selectivity' in attracting a certain kind of firms and institutions. Only if these firms and institutions can work together in a truly synergistic way through co-operation and competition, will a genuine place for R&D activities be formed.

Secondly, this study highlights the importance of questioning planning ideologies before planning actually takes place. As science park formation is mainly a long-term commitment of vast resources, it will be counter-effective to *assume* that elaborate facilities, benefits and incentives or even spatial proximity will encourage the specific planned functions. This implication brings us back to Massey *et al.*'s (1992) critical study of science parks as "high-tech fantasies". Future planning for science parks must take into account the wider relations between the role of R&D activities in host economies and the (urban and regional) institutional fabric in which technological innovations are embedded. Planning for science parks also needs to anticipate and incorporate social needs—both initial and changing ones. With an indication of how 'fault areas' may be identified, the onus now is to identify, repair and foster social relations that are so critical to the dynamism and success of a science park. Although science parks vary in function and form, there are two distinct phases of park development in almost all of them: the institutional and the entrepreneurial phases (Cox, 1985, p. 20). The former phase is fairly predictable, associated with the addition of services and facilities to attract smaller research facilities. The latter phase develops later and is less predictable as its development depends on many variables. The ability of a park to survive on its own with as little support as possible will depend on its development success during the entrepreneurial phase. There are too many science parks in the world that are still caught in the institutional phase of development. The greatest challenge ahead for most of them is to move into the entrepreneurial phase of development. Otherwise, these places will remain as no more than "high-tech fantasies" in a globalising world of rapid technological changes and greater economic uncertainties.

Notes

1. The Organisation for Economic Co-operation and Development (OECD, 1982) defines R&D as

   > The creative work undertaken on a systematic basis in order to increase the stock of knowledge, including the knowledge of man (*sic*), culture and society and the use of this stock of knowledge to devise new applications.

   R&D consists of four main types: basic research—the search for new knowledge; applied research—determining means to meet the new concept; development—production of useful materials; and, product and process—development of product. The type of R&D conducted is a crucial consideration in the evaluation of the impact of R&D activities on the host economy. Such a working definition, however, is far from complete. It assumes that R&D activities are consecutive (Myers and Rosenbloom, 1996) and that effective research (improving the knowledge base) equates to productive research (organisational capabilities needed to realise vision) in a linear process. While the present authors do not subscribe to the linearity in defining R&D activities, they accept the above four dimensions of R&D activities that must be seen as mutually constitutive and interrelated. In this sense, it is hard to imagine research without development and vice versa. R&D is therefore taken as an integral term in this paper that refers to innovative activities leading to new ideas and knowledge.
2. The science park notion was pioneered in the US in the 1950s, after Stanford University successfully allocated part of its campus for commercial developments by university scientists in 1951. The concept emerged in the UK in the 1960s and, by the mid 1980s, had become a fashionable policy in local and regional economic development in North America, Europe and parts of Asia (see, for example, OECD, 1982; Gibb, 1985; Monck, 1985; Wang, 1994).
3. Studies of R&D activities often rely on interviews and public information (Gassmann and Zedtnitz, 1999). Conducting surveys best covers the empirical aspects of the research work. Interviews are useful for understanding actors' responses to daily operations (see Eisenhardt, 1989; Demirag, 1996; Numagami, 1998). In this study, a combination of survey and interview method was used. A total of 166 postal survey questionnaires were sent to all tenants of the Singapore Science Park in early 2000. The sampling criterion was that the firm's mailing address had to be located in the Singapore Science Park. Only firms in technical operations were registered. Such facilities as eateries and childcare centres were omitted. The Singapore Science Park directory on the internet served as the primary list (http://www.sciencepark.com.sg). The Park's tenants were telephoned subsequently to ensure a greater survey return, during which it emerged that 12 firms were no longer in operation, 2 companies indicated that they were 'dormant', and another 2 were in the process of moving out of the Park. This reduced the effective survey sample size to 150 firms. In all, 34 (22.7 per cent) responses were received. This survey was followed by 12 in-depth interviews with firms, 2 with research institutes and 2 with organisations directly related to the Park. These firms were selected on the basis of their differences in origin, type of firm, employment, industry,

main function and proportion of R&D expenditure. All 16 interviews were recorded and transcribed.

4. With effect from 1 January 2002, the NSTB has been renamed as the Agency for Science, Technology and Research (A*Star; see http://www.a-star.gov.sg).
5. The exchange rate in July 2002 was about US$1 to S$1.8.
6. Interview with the NSTB spokesperson; 29 February 2000.
7. A wholly-owned subsidiary of the Jurong Town Corporation since its incorporation in 1990, Arcasia is the developer and manager of the Singapore Science Park. It was renamed as Ascendas on 8 January 2001 following its merger with JTC International, another subsidiary of the JTC.
8. Interview with Arcasia's spokesperson; 1 March 2000.
9. Interview with an R&D facilities manager; 19 February 2000.
10. Interview with an IT project director; 24 February 2000.
11. Interviews with the NSTB spokesperson, 29 February 2000; and Arcasia's spokesperson, 1 March 2000.
12. Interviews with an IT SME and a German engineering SME.
13. Interview with the facility manager of a US chemical firm, 23 February 2000.
14. Interestingly, awareness of other firms in the same industry is most distinct in the food/flavours industry, as observed from the three firms interviewed. The typical response from the interviews indicates little awareness of other firms within the same industry.

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