Science Parks: A Critical Assessment

Hooshang Amirahmadi
Grant Saff

During the 1980s, many policymakers facing decreasing revenues and increasing unemployment looked to technology-led development to pump new life into their sagging regional and national economies. One of the ways they attempted to promote this high-tech strategy was through the creation of science parks. But although these parks have demonstrated some potential for enhancing economic growth, they are hardly the economic quick fixes some policymakers believe them to be: successful parks often have taken a decade or more to become economically viable, their failure rate is high, and their regional and national economic impacts have been exaggerated. State or governmental support is essential to the success of a science park. This assistance may take many forms—from direct state subsidy, to provision of infrastructure, to simply directing government-related research and development contracts to science park tenants. Locating a park near certain urban features—good transportation linkages, a high-quality residential environment, a university, and a pleasant working environment—is also essential. Science parks are not, in themselves, the answer to promoting regional or national high-technology-led economic development, but they can be one of a number of options available to planners and policymakers as part of a well-thought-out and coordinated development strategy built on regional or national strengths, rather than artificial supports for costly and uncertain high-technology strategies.

Since the early 1980s, the subject of science parks has generated a vast amount of both direct (Gibb 1985; Monck et al. 1988; Goldstein and Luger 1991; Massey et al. 1992) and indirect literature (Malecki 1991). Much of the former literature touched on science parks within the broader context of technology and economic development, whereas much of the latter literature focused on particular themes or aspects. Although the literature is very detailed and thorough, until recently there has been little attempt to provide a comprehensive synthesis and evaluation of what science parks are, why they are established, how and where they evolve, whether they are successful in achieving the goals for which they are designed, and what the future holds for these parks.

One reason there have been few such comprehensive and critical evaluations of science parks is their diversity in form and function. Science parks differ in size and structure, in the amount and type of employment they provide, and in goals and development histories. Despite these differences, the parks exhibit enough common characteristics (such as their predominant function) for them to be categorized as "science parks."

This article aims to provide a comprehensive overview of the debates and issues concerning science parks to provide a basic synthesis, to point to areas that need

HOOSHANG AMIRAHMADI is professor and chair of the Department of Urban Planning and Policy Development at Rutgers, the State University of New Jersey, where he also serves as director of Middle Eastern Studies.

GRANT SAFF is a doctoral candidate in the Department of Urban Planning and Policy Development at Rutgers, the State University of New Jersey.

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further research, and to offer an assessment of the efficacy of science parks.

The article is divided into four parts. Part 1 reviews definitions of science parks and establishes a working characterization. Part 2 sets out the origins and development of these parks. The first section of part 2 focuses on the development of science parks in the United States, which contains over half of the science parks in the world. The second section looks at developments in the rest of the world. Part 3 sets forth the rationale for the development of science parks, with special emphasis on the rapid growth of science parks in the 1980s. Part 4 is a critical evaluation of the achievements and future role of these parks.

TOWARD A CHARACTERIZATION OF SCIENCE PARKS

There is no single definition of a science park. Although this is not surprising given the diverse forms and characteristics that science parks exhibit, the lack of unanimity on a definition has nevertheless created some conceptual confusion within the literature. Writing about science parks in Germany, Allesch (1985) offers a fairly precise definition. He distinguishes between research parks, innovation centers, and science parks. A research park is one in which young firms or detached sections of large companies carry on research and development in relatively close cooperation with a nearby university or research establishment and where the development of prototypes, but not mass production, is allowed. An innovation center provides new high-technology firms with an optimum chance of survival and development by offering an extensive range of services, proximity to university institutions, and the possibility of integration into the local and regional innovation network. Science parks, on the other hand, are a new way of locating industries: existing firms in innovative technology areas are offered attractive surroundings and proximity to research establishments.

Allesch's definition of science parks has two limitations. First, it excludes the possibility of new firms (start-ups and spin-offs) forming within the parks. This omission is significant because one of the primary rationales for the promotion of science parks is the impetus they generate for small-firm formation. Second, it is difficult to sustain his distinction between science parks and research parks in practice. In reality, many parks include a combination of the three categories set out by Allesch.

The theoretical distinction between science parks and research parks is important, however, because some of the literature for the United States treats the latter as a distinct subset of science parks (see Everhart n.d.; Fusi 1991), whereas others use the terms interchangeably (Goldstein and Luger 1991). Most of the literature (see for example, Goldstein and Luger 1989, 1990, 1991; Malecki 1991) is not emphatic enough about this distinction. For the purpose of this article we define research parks as a subset of science parks that have formal links to a university and where the primary activity of the majority of tenants is research and development (R&D). As such, statistics with regard to science parks cited in this article do not disaggregate research parks from the umbrella term of science parks.

Monck et al. (1988) choose the purely functional definition of science parks, developed by the United Kingdom Science Park Association (UKSPA), as the one that comes closest to capturing the diversity of science parks. UKSPA defines a science park as a property-based initiative that includes the following features: (a) it has formal and operational links with a university, other higher-education institution, or research center; (b) it encourages the formation and growth of knowledge-based businesses and other organizations normally resident on site; and (c) it has a management function actively engaged in the transfer of technology and business skills to the organizations on site and also attempts to link the parks to a higher-education institution—especially on issues of science and technology (Monck et al. 1988, 64; see also Massey and Wield 1992, 412). This definition, like the one developed by Allesch, is difficult to sustain in the United States where links between science parks and universities are not always as formal as this definition implies. Moreover, in many respects, the definition seems closer to the characterization of a research park than a science park. The term *property-based initiative* makes the definition particularly vague and opens the door for confusion with other types of parks or economic activity locations.

Many authors (see Joseph 1989; Goldstein and Luger 1991; Malecki 1991) use the terms *science park* and *research park* interchangeably. In Joseph's view, these parks promote the growth of large technology-oriented complexes (TOCs). He identifies four types of TOCs, distinguished by the factors that contributed to their initial development: (1) TOCs whose growth is principally the product of locally initiated firms and spin-offs, such as Boston's Route 128 and Silicon Valley; (2) research-oriented TOCs usually restricted to a park site, such as Research Triangle Park in North Carolina; (3) TOCs initiated by attracting manufacturing facilities of high-technology companies, as in Phoenix, Arizona; and (4) TOCs that result from large expenditures of government funds, as represented by U.S. space and defense expenditures in Houston, Texas (Joseph 1989, 173). These archetypes may overlap, and a single TOC may contain elements of more than one model. Science parks have been established that incorporate all of these models, but only in Joseph's second model are science parks explicitly established to promote either regional development, R&D, high-technology-led growth, or a combination of these three.

Goldstein and Luger (1989, 1990) provide a more satisfactory definition. They define a science/technology/research park as a business park where the primary activity of the majority of establishments is research and/or new product or process development—distinct from manufacturing, sales, headquarters, or other similar business functions. Typically, the proportion of a park's workforce made up of scientists or engineers with advanced graduate degrees is used as a proxy for measuring R&D activity. The advantage of Goldstein and Luger's definition is that it allows science parks to be distinguished from areas with spatial concentrations of high technology that are not organized under a single entity (and which Joseph calls TOCs), such as Boston's Route 128. Goldstein and Luger exclude business incubators (unless the organizations occupying the incubator are engaged primarily in R&D activity) and technology centers from their definition. The main purpose of technology centers, according to Goldstein and Luger, is the coordination of technological developments and technology transfer among universities and other research organizations.

Malecki (1991) also uses the terms research parks and science parks interchangeably and defines them as potential cores of new Silicon Valleys. This definition is based on their function as potential core areas for regional development. He also develops a working definition based on the physical characteristics of the parks:

> Given the clean office and research atmosphere of R&D facilities, many of them have settled into the suburban office and industrial parks that are now a commonplace location for economic activity in metropolitan areas. Whether called science parks, research parks or technology parks, these more specialized developments cater to the preference for campus-like setting with low-density, often dispersed, building sites. (P. 308)

The use of the terms science parks, research parks, and technology parks interchangeably illustrates the difficulty in making concrete distinctions between the different types of parks.

A more recent conceptualization adopts what is called a "critical realist" methodology (Massey et al. 1992; Massey and Wield 1992). According to this conceptualization, no causal relations are assumed to exist between science parks, what it may take to establish them, and what may result as a consequence of their operations. This is a response to the more established conceptualization that argues for causal links between the preconditions for the formation of science parks and their expected outcomes. According to Massey and Wield (1992), this popular characterization often is based on a lack of extensive empirical investigation of the more hidden preconditions and outcomes. They argue that science parks are "symbolic of something wider than themselves; they are a condensation of a number of broader issues. In particular, they are symbolic of a view . . . of the relation between science, society, and space" (412). The archetypal science park is based on three elements: first, a linear model of scientific investigation and industrial innovation; second, particular characteristics of spatial form and content; and third, it is a property development. The importance of the property development characteristic is that even when a public sector-private sector partnership is established, the profit motive of the latter continues as the driving force. They argue that each of these elements has potential consequences and causal powers that are quite different from those put forward by policymakers, and that these potential consequences are often detrimental to the objectives that science parks are established to achieve. Massey and Wield (1992) argue, therefore, that although science parks may in part produce their popularly expected outcomes, they also produce less visible consequences, such as social inequity, uneven development, and hindrance of industrial regeneration.

To capture the diversity of science parks and avoid the prevailing conceptual confusion, it would seem that a characterization of science parks is needed that is as inclusive as possible without becoming totally meaningless. Such a characterization would include both preconditions for the establishment of the parks and their expected outcomes. As far as possible, we have used our characterization (given below) as the guide for considering the origins and development of science parks. On occasion, the terminology of the original authors is used to avoid distorting their intentions. Note also that this broader characterization allows for more inclusiveness than those developed in the works reviewed so far. This fact is reflected in the use of Fusi's (1991) estimated number of science parks in the United States of 285, rather than the number given by Goldstein and Luger (1991) for research/science parks of 116.

Science parks are a type of business park where the primary activity of the majority of the establishments is industry-driven R&D. As such, mass production and basic research usually are not undertaken in these parks. Another attribute of science parks is their integrated spatial structure. Various elements are logically connected and interdependent in terms of both social and technical division of labor. Thus it is no wonder that science parks are often both perceived and marketed as single entities rather than TOCs (although science parks are often a part of TOCs). Science parks are also expected to generate new high-tech firms through spin-off or other forms of new investments. Most science parks also feature a parklike, low-density landscape. Links with a research facility (a university or institute, for example) are often a precondition for the establishment of science parks. Further, the labor market should offer a highly skilled workforce or, at the least, the potential for attracting such skills. As property developments, science parks normally remain based on a profit motive, even when created through a partnership between the private and public sectors. Finally, we include all science parks that are perceived by the tenants, developers, policymakers, and the public as being science parks. Although the last point might seem tautological, it is important not to exclude parks that see themselves as science parks but that might not fit the tighter definitions developed by Allesch (1985) or Monck et al. (1988), among others.

ORIGINS AND DEVELOPMENT OF SCIENCE PARKS

During the 1980s, science parks were a rallying symbol for beleaguered regions, local governments and universities faced with a changing national and world economy, the decline of manufacturing industry, and severe cuts in central government funding. The perceived high-tech success of regions such as Silicon Valley in California, Research Triangle Park in North Carolina, and Boston's Route 128 assumed mythical proportions, and localities all over the world vied with each other to replicate their success. High-technology-led development was seen as the vehicle for renewed economic growth, with science parks being the means of drawing these firms into a locality. Goldstein and Luger (1989) comment that there was nearly a 300 percent increase in the number of parks in the United States between 1982 and 1989. This rapid rate of growth was not confined to the United States. In Britain, for example, the number of parks grew from two in 1972 to sixty-five in 1991 (Fusi 1991).

Science parks display an astonishing degree of diversity in virtually all aspects. In employment size, they range from parks with less than one hundred workers to Research Triangle Park's thirty-two hundred. In physical dimensions, they range from under three acres to over more than sixty-five hundred acres. They differ in organization and ownership: most, but not all, are linked to a university; some are publicly owned, and others operate as private developments (Goldstein and Luger 1990). In a review of 116 research parks in the United States, Goldstein and Luger (1991) found that 25 percent were units of public or private universities, 16 percent were owned by state or municipal governments, 23 percent were nonprofit corporations or foundations, 15 percent were owned by for-profit corporations, and the remaining 21 percent were joint public-private ventures. Types of firms found in science parks also vary, ranging from R&D divisions of multinationals, like Hewlett Packard and IBM, to small, recently established, high-technology enterprises. Given this diversity, this section can do no more than give a very schematic history of the development of science parks. We focus on their development within the United States because this is where the concept originated, and it is where approximately one-half of the world's science parks are found.

TABLE 1. Leading Countries in Number of Science Parks, 1991

1. United States	285
2. United Kingdom	65
3. France	43
4. Canada	38
5. Japan	29
6. Australia	22

SOURCE: Fusi (1991, 610).

Science Parks in the United States

The United States has by far the greatest number of science parks in the world, with 285 (see Table 1). It also has six of the top ten parks in terms of the number of employees (see Table 2). Geographically, the parks are spread throughout the continental United States, with a disproportionate share located in the south (see Table 3).

According to Goldstein and Luger (1990), about 40 percent of the parks with tenants in 1985 were located in large metropolitan regions (over 500 thousand population), about 50 percent were located in small metropolitan areas or nonmetropolitan places (under 200 thousand population) with at least one major research university or federal research complex, and the remaining 10 percent were located in small to medium-sized centers (under 500 thousand population) without a major research institution. They note that the number of parks being developed without links to a major research facility is increasing. This observation reinforces the need expressed in the previous section for attempting to clarify the position of research parks vis-à-vis science parks.

Historically, the establishment of science parks in the United States has conformed to two main patterns. The first is the spontaneous development of high-technology agglomerations within which science parks have been established, such as that developed around Boston's Route 128 (conforming to category 1 in Joseph's [1989] typology). The second is the deliberate creation of large research or science parks designed to boost the fortunes of particular regions, universities, or both. The Stanford Research Park and Research Triangle Park in North Carolina fall into this latter category (conforming to category 2 in Joseph's typology).

TABLE 2. Ten Largest Science Parks—Number of Employees, 1991

1.	Research Triangle Park, North Carolina	32,000
2.	Stanford Research Park, Palo Alto, California	26,000
3.	Cummings Research Park, Huntsville, Alabama	18,000
4.	Akadem Gorodok Science City, Novosibirsk, Russia	17,900
5.	Tsukuba Science City, Ibaraki, Japan	15,500
6.	Sophia-Antipolis Science Park, Valbonne, France	14,500
7.	University Research Park, Charlotte, North Carolina	9,600
8.	University City Science Center, Philadelphia, Pennsylvania	6,000
9.	Rennes Atlante, Rennes, France	4,900
10.	Central Florida Research Park, Orlando, Florida	4,000

SOURCE: Fusi (1991, 613).

TABLE 3. Leading States in Number of Science Parks, 1991

1. California	31
2. Florida	22
3. Michigan	17
4. New Jersey	16
5. Colorado	14
6. New York	13
7. Texas	13
8. Georgia	12
9. Ohio	12
10. Maryland	11

SOURCE: Fusi (1991, 614).

Route 128 is a major peripheral highway built during the 1950s, and it lends its name to the entire Boston-area electronics complex (Malecki 1986). Covering a thirty-mile radius from the center of Boston, the area employed approximately 250 thousand people in the electronics and related industries in 1983 (Monck et al. 1988). Monck et al. place the locus for this growth on the formation of high-technology businesses by faculty members of the Massachusetts Institute of Technology (MIT). They also note the role played in the area by the location of a single big firm, Digital Equipment corporation. Markusen et al. (1986) note the crucial role attributed to commercial spin-offs from research undertaken at the area's major universities, much of it funded by defense contracts. Malecki (1986) agrees and comments that the presence of MIT alone does not explain the growth of high-technology firms along Route 128—rather, it is the combination of top universities in the area that is responsible for attracting academics, students, and firms. Malecki also notes the role that existing cultural and residential facilities, such as good schools and universities, played in fostering growth.

In the initial stages of development, state and government policies were of little importance in contributing to Boston's high-tech success (Malecki 1986). Of more importance was the historical innovation of firms located in Boston and its suburbs, which dates back to before World War II. This innovation enabled the area to benefit from defense contracts both during and after World War II. In 1986, Massachusetts had the highest per capita level of military research in the country (Malecki 1986). Local government policy was supportive to the extent that it permitted the development of industrial parks along Route 128. At the state level, Massachusetts attempted to match the programs of other regions competing for high-technology industry (Malecki 1986). The state lowered the personal tax burden, backed a university-industry cooperative microelectronics center and, on a more subtle level, used public expenditures to support the attractive residential and recreational environment of the Boston area.

Botkin (1988) draws three lessons that should serve as warnings for other regions seeking to emulate the development of Route 128. First, building a high-technology region takes time. Second, government policies and incentives are needed more in the depression part of the business cycle than in the inception point; such incentives are probably more effective at these low points because it is easier for government to soothe people than to stimulate them. Third, high tech is no more stable or unstable than other industries.

The first generally accepted science park was the Stanford Research Park in Palo Alto, California, conceived in 1951. The park was the brainchild of Frederick Terman (nicknamed the "godfather of Silicon Valley," see Larson and Rogers [1988]), a professor of electrical engineering at Stanford University, who attempted to find a way to make money for the university and improve its international reputation. The park, situated on university land, began functioning in 1952 and is credited as the catalyst behind the economic development of what has come to be known as Silicon Valley. Since 1952, the park has grown into a complex of nine million square feet, occupied by fifty-nine businesses employing twenty-eight thousand workers (Goldstein and Luger 1991). In the early 1980s, Silicon Valley, of which the park is part, was one of the fastest growing regions in the United States, creating about forty thousand new jobs per year (Larson and Rogers 1988). Terman is also credited with giving a start to Hewlett-Packard in 1938, by advancing $538 to the embryonic firm so that it could start production of a variable frequency oscillator. He was rewarded for his foresight when the Hewlett-Packard Corporation chose to locate in the research park—a decision that has benefited the park in terms of income, prestige, and employment.

Monck et al. (1988) maintain that the initial success of the research park was premised on the contribution made by a single large firm, Fairchild, that settled within the park in 1957. Unlike MIT and the Boston area, the Stanford faculty has been the source of relatively few spin-offs (Malecki 1986). Most spin-offs developed from former Stanford students who went to work at firms such as Fairchild and Hewlett-Packard. Malecki (1986) also comments that, as with Route 128, the state and local government had little role in the successful development of Silicon Valley's high-technology activity. The role of local government has been confined to facilitating development by the annexation and rezoning of land, extension of utilities, creation of industrial parks, and road construction. Like Route 128, however, federal government defense contracts have been important for the development of the area.

Larson and Rogers (1988) identify six factors that were essential to the rise of Silicon Valley: (1) availability of technical expertise, (2) availability of preexisting infrastructure, (3) availability of venture capital; (4) job mobility, (5) information exchange networks, and (6) spin-offs from existing firms. These six factors, combined with those identified by Monck et al. (1988) and Malecki (1986), provide a fairly comprehensive list of the policies and factors necessary for the promotion of high-technology-led development.

Vogel and Larson (1985) provide a very useful analysis of how Research Triangle Park in North Carolina was established. Its history is worth detailing because it has served as the role model for science parks around the world. After World War II, North Carolina's traditional industries (furniture, textiles, and tobacco) entered a period of relative decline. An alliance of businessmen and state politicians pushed for the establishment of a research park based on the examples of Stanford Research Park and Boston's Route 128. From its outset in the early 1950s, the group attempted to get academics from North Carolina's three universities (Duke, the University of North Carolina at Chapel Hill, and North Carolina State) interested in the project. The idea was to establish a sixty-seven-thousand-acre research park to attract companies that wanted to expand research activities in areas in which the universities had great strength. After an attempt by commercial developers ("Pinelands") failed in 1958, a nonprofit foundation funded by public donations was set up by a coalition of businessmen and politicians under the name Research Triangle Park to market the concept.

Research Triangle Park consists of three parts: (1) a nonprofit foundation with tax exempt status owned by the universities; (2) the park, a profit-making subsidiary of the foundation with profits from sales and rentals going to the foundation to fund further research; and (3) the nonprofit Research Triangle Institute, established as a research organization independent of the foundation and the profit-making part of the park (Vogel and Larson 1985; see also Goldstein and Luger 1991). The attractions were to be the park's relationship with the three universities, the parklike atmosphere (which did not allow any manufacturing facilities and allowed tenants to cover a maximum of 10 percent of the land with buildings), and the provision of infrastructure by the state. Initial progress in attracting companies was slow, and it took until 1965 for the park to begin to break even. Partly on the insistence of IBM, the park's rule about the percentage of land that could be covered with buildings was eased from 10 to 15 percent, and the area allotted for production was expanded. It was only through state action, however, that the park became viable. State government spent large sums of money to improve the regional infrastructure, such as constructing a new highway and building an airport. The legislature also passed a community college act to provide local skilled workers for the new firms.

North Carolina's low unionization rates (among the lowest in the country) also helped the park attract tenants. Firms were able to take advantage of below-average labor costs for R&D workers. The federal government provided help by establishing the National Institute of Environmental and Health Science in the park in 1965, and by 1981 the federal government had sited five federal laboratories within the park. It was only when IBM decided to move into the park in 1965, after seven years of negotiation, that its success was assured. The park has grown into the largest science park in the world in both employment and physical size. It currently employs thirty-two thousand people, covers an area of twelve million square feet, and in 1987 its annual payroll was more than $1 billion (Hayes 1987).

The three examples cited above have certain commonalities. In each case, the relationship between the park or area and the local research universities was an important catalyst for development. Although the degree to which firms continued to have close ties with universities is a subject of debate, there is little doubt that these links were important in the initial phases of development. A further commonality is that the parks were established in so-called high amenity areas that provided attractive living environments for highly qualified research workers. Another commonality is the role that a single large firm played in guaranteeing economic success: Digital Equipment Corporation in Boston, Fairchild at Stanford Research Park, and IBM at Research Triangle Park. State government assistance was crucial to the success of the parks and economic development of their surrounding areas. Finally, in all three cases, individual initiative provided the starting point and set the foundation for their eventual growth and sustainability.

The physical layouts of the Stanford Research Park and Research Triangle Park have become the norm for science park development throughout the United States and the rest of the world. This generally consists of a parklike environment of low-density and well-designed office facilities, often including recreation facilities for employees. As competition to attract firms has increased among parks, facilities have become more elaborate. The San Diego Tech Center, for example, boasts a Japanese teahouse, two tennis courts, two sand volleyball courts, a large heated swimming pool, a weight room, jacuzzis, an aerobics center, and a jogging track—all free to employees at the center (Nunes 1985).

There is, however, one crucial difference among the three main examples cited above. Route 128 was a spontaneous outgrowth of economic conditions, local economic policy, a preexisting culture of innovation, and the convergence of world-class universities. Stanford Research Park and Research Triangle Park, in contrast, were planned creations and designed to foster technology, innovation, and regional economic growth. In the cases of both Route 128 and Stanford Research Park, the existing urban agglomerations played an important role in attracting high-technology firms with a minimum of state investment. At Research Triangle Park, however, the amenities, facilities, and infrastructure had to be provided at a substantial cost to the state. From the perspective of national policy, this suggests that in most cases, existing urban agglomerations are more efficient and cost-effective locations for the establishment of science parks than remote and peripheral areas.

Saxenian (1989) emphasizes the very different attitudes toward state intervention held by the high-tech industrialists of Route 128 and Silicon Valley. She argues that the Route 128 industrialists repeatedly clashed with the local public sector and that they remain ideologically opposed to government intervention of almost any sort. Industrialists in Silicon Valley, however, were explicitly committed to cooperation with local government and consistently supported an active state role in planning regional development. She ascribes this difference in attitude primarily to the political environment in which the processs of interest organization and identity formation occurred. One important implication of Saxenian's work is that before planners attempt to establish regional or national policy guidelines for high-tech growth, they should undertake microstudies of individual areas to assess the local attitudes toward state intervention. This will not only allow planners and policymakers to anticipate possible sources of opposition but will also allow them to tailor plans to fit individual regional circumstances.

It is important to note that, in the United States, the state rather than federal government has played the key role in promoting science parks. This generally has been done through the provision of infrastructure and land, tax breaks and tax holidays, promotion—primarily through marketing campaigns and lobbying—and other fiscal and physical incentives. Malecki (1991) sees an increasing trend toward public-private partnerships in economic development and in the establishment of science parks in particular. For example, Connecticut has backed the New Haven Science Park, centered at Yale University, with $4.4 million (see also Kysiak 1989; McQueen 1988). One reason for this trend is the budget crunch in the 1980s that fell heavily on local and state governments as well as universities. Many universities developed science parks to increase revenues. Typically, this has involved making underused university land available for the development of the park (see Everhart n.d.). As Malecki (1991) points out, this seldom has been done without the support of local city or state governments. Everhart notes that Northwestern University is in the process of developing a $400 million research park in Evanston, Illinois scheduled for completion in 1997. This is a joint venture between the university, a prominent local developer, and the city of Evanston. Everhart estimates that the city will gain $10 million per year in property taxes alone, or about one-sixth of the 1990 municipal budget. This type of partnership is becoming the norm in science park development, but it is usually the state or city authority—rather than the university—that takes the lead.

The federal government has given only indirect support through defense or other contracts, expenditures for R&D (in 1985, 59 percent of this expenditure was on defense-related R&D [see Malecki 1991]) or the siting of federal agencies within these parks. Given the high level of defense spending in the United States, this indirect role must have had a substantial effect on many of the firms located within the parks. There seems to be a correlation between the siting of federal facilities and the growth of adjacent science parks. The Cummings Research Park in Huntsville, Alabama, is home to the Alabama Space and Rocket Center; the Central Florida Research Park in Orlando is near the John F. Kennedy Space Center in Cape Canaveral. Both the Stanford

Research Park and the University City Science Center in Philadelphia have benefited from federal spending, on nuclear research and medical technology, respectively.

The correlation between federal R&D spending, particularly defense-related R&D, and the success of science parks has not received adequate attention in the existing literature, and it is an area that would profit from further investigation. If defense spending has been crucial for the success of either science parks or individual firms located in these parks, then the implications of decreased defense spending on the future of science parks is in need of urgent study.

Science Parks in the Rest of the World

After the United States, the United Kingdom has the second largest number of science parks. These parks and related high-technology growth centers have been the subject of a number of studies (see Currie 1985; Hall et al. 1987; Keeble 1989; MacDonald 1987; Massey et al. 1992; Massey and Wield 1992; Monck et al. 1988; Segal 1986, 1988; Segal Quince Wicksteed 1985). In 1991, there were sixty-five science parks in the United Kingdom, containing more than one thousand tenants and employing some fifteen thousand people (Fusi 1991). Using the more rigorous UKSPA definition, Massey et al. (1992) count only thirty-eight science parks. They excluded many parks because of the lack of a formal link with an academic establishment. The first science park in the United Kingdom was established by Cambridge University in 1973. The growth of the park was slow, with only seven firms located in the park by 1978. The park greatly expanded in the mid-1980s, however, growing to sixty-eight firms by 1986, and has provided a catalyst for the growth of high-technology companies in the Cambridge region (the so-called Cambridge phenomenon). By January 1986, an estimated 16,500 workers were employed in approximately 350 high-technology companies in southern Cambridgeshire, providing 11.4 percent of the total employment in the area (Keeble 1989, 158).

The development of the Cambridge TOC (which includes the Cambridge Science Park) illustrates certain characteristics pertinent to the history and development of science parks worldwide. Keeble (1989) identified six characteristics important to the growth of the Cambridge TOC:

1. *Recent growth.* Despite the establishment of the science park 1973, Cambridgeshire experienced a net decline in high-technology manufacturing employment during the period between 1971 and 1981. Since 1981, there has been a turnaround, with an average of thirty new high-technology firms per year establishing in the area.
2. *Entrepreneurship, independence, and age.* Most of the firms in the Cambridge TOC are relatively young high-technology companies formed by individual entrepreneurs. In1986, 53 percent of all high-technology companies operating in the region had been in operation for five years or less. These firms were generally smaller than older firms and accounted for 24 percent of high-technology jobs. Of high-technology firms, 75 percent were indigenous, created by local entrepreneurs. These small firms, however, are being bought out increasingly by multinational firms, indicating a likely change in the pattern outlined above.
3. *Type of activities.* The types of high-technology firms vary widely, with electronics being the single largest sector (21 percent). R&D accounts for the main function of these firms (42 percent), followed by manufacturing (37percent).
4. *University links.* Over half of the firms surveyed presently maintain, or had maintained, links with local research bodies—90 percent of these being university departments.
5. *Employment impacts.* Between 1979 and 1987, there was a net employment growth of six thousand jobs out of a total local labor force of 120,000. This growth must be judged against a 27 percent manufacturing job decline since 1979. The bulk of this employment has been in highly skilled technical, research, or managerial positions. In 1986, semiskilled and unskilled manual labor accounted for only 11 percent of the TOC workforce.
6. *Local multiplier effects.* There have been considerable multiplier effects for three reasons: first, Cambridge high-technology firms sell the bulk of their products outside the local economy; second, significant local purchasing and subcontracting linkages exist; and third, the above-average salaries and wages paid to the workforce in local TOC companies produce a higher effective demand, which translates into a high local multiplier. Based on work by Moore and Spires (1986), Keeble estimates a local employment multiplier for the high-technology sector of approximately one indirect job for every new high-technology job created.

The characteristics identified by Keeble are useful for identifying the origins, size, linkages, types, and age of firms that locate in science parks. His findings with regard to the efficacy of science parks must be viewed cautiously. Keeble himself warns that "the cost-effectiveness of a science park policy must, however, be carefully evaluated in each specific regional context, because as Segal stresses (1988), science parks are not a sufficient or even necessary condition for local technology-based development" (168). Jowitt (1988), who studied a science park in Bradford, West Yorkshire—which enjoys none of the locational or institutional advantages of Cambridge—concludes that the chances of its success are small.

The level of local multipliers will also vary to a considerable degree. Massey et al. (1992) argue that the technological multipliers from science parks are relatively low, and thus most of the multipliers generated by science parks are income multipliers. Hence jobs created by the science parks depend on the high wages of others. Many of the jobs so generated are low-paying unskilled jobs in the service sector; they argue, therefore, that high-tech development strategies as represented in science parks can actually exacerbate increasing occupational inequality. This is an issue in need of further investigation within the literature.

Massey et al. (1992) estimate that, unlike the United States, the bulk of investment (59 percent) in land and buildings in the thirty-eight U.K. science parks recognized by UKSPA have come from the public sector (local authorities, academic institutions and development agencies). It is important to note that although public sector investment has been fairly even geographically, private sector investment has been greatest in those regions undergoing economic growth (the southeast and the southwest regions). Massey et al. comment that this pattern of investment is likely to increase the process of uneven regional development and argue further that public sector grants and research expenditures have tended to favor science parks in the south—particularly Cambridge—hence reinforcing the spatial pattern of uneven regional development.

As in the United States, the relationship between U.K. government defense spending and the success of science parks needs to be investigated. If it is found that the growth of U.K. science parks has depended on the high level of defense spending during the 1980s, then cuts in this spending will likely have severe negative implications for the future of many of the firms in these parks and, perhaps, for many of the parks themselves.

Besides the United Kingdom, there was a rapid growth of science parks in continental Europe during the 1980s (see Gibb 1985). This was most pronounced in Germany (Allesch 1985), and France (see Dyckman and Swyngedouw 1988; Laffitte 1988; Perrin 1988; Scott 1988). The most successful of the French technopoles (urban research parks) is the Sophia-Antipolis, situated outside Nice (Perrin 1988). Conceived in 1969, this park has origins similar to that of Research Triangle Park. The project was formulated primarily through the initiative of the director of a French *école*, who sought to emulate the success of Route 128 and Silicon Valley. In contrast to Route 128 and Silicon Valley, however, Sophia-Antipolis was situated in a peripheral region with a relatively new university. Perrin (1988) argues that in fifteen years Sophia-Antipolis has created six thousand jobs (of which more than four thousand are in high-tech activities) in a peripheral area with little industrial tradition and with a relatively new university. Dyckman and Swyngedouw (1988) take a less favorable view on the regional success of Sophia-Antipolis. They argue that, despite Sophia-Antipolis's strong showing in high-tech development and job creation, the industries of the region lost more than 131 thousand employees between 1978 and 1988—a drop of 16 percent. Such an interpretation implies that the growth of high-tech industry in declining regions is unlikely to offset overall trends of job loss.

Perrin (1988) also argues that Sophia-Antipolis represents an example of a "territorial type" technology policy in that it was promoted at a local (territorial) level rather than at the state level. This interpretation differs from that of Dyckman and Swyngedouw (1988) who argue that French policy was part of a "modernization" strategy. The development of Sophia-Antipolis remains atypical from the French norm in science park development, which could account for some of the difference in interpretation. Unlike Sophia-Antipolis, most science parks in France are situated near major urban areas. Moreover, unlike the United States, French technopoles have always enjoyed the support of both national and local governments (hence a combination of the "territory" and the state). Furthermore, although Perrin argues that there was no officially accepted theory behind the promotion of technology centers, this is unlikely given the genesis of growth pole theories in France. According to Malecki (1991), the two main factors influencing high-tech government policy in France have been the desire for the decentralization of industry from Paris and the lingering memories of the growth pole theories of the 1950s (see also Goldstein and Luger 1990).

Among the leading industrial countries, Japan has the most ambitious plan for deliberate high-technology development (Glasmeier 1988; Kawashima and Stohr 1988; Malecki 1991; Markusen 1991; Masser 1990; Onda 1988; Tatsuno 1986, 1988). In 1983, the Ministry of International Trade and Industry (MITI) embarked on the Technopolis Program in an attempt to steer dynamic or propulsive high-technology industries toward particular regions to generate regional self-sustaining growth and reduce regional inequalities. This policy reflected a trend in Japanese planning dating back to the mid-1960s aimed at promoting regional development. The Tsukuba Science City, modeled after Research Triangle Park, was founded in 1963 and is a direct precursor of the Technopolis Program. Science City is located 60 kilometers north of Tokyo and is now home to two universities and fifty national research institutes (Malecki 1991). The 1983 technopolis law specified the site location criteria to be used by MITI, including (1) proximity to a city of at least 150,000 people, to provide urban services; (2) proximity to an airport or bullet train station; (3) an integrated complex of industrial, academic, and residential areas; and (4) a pleasant living environment (Malecki 1991, 301). The selected cities provide infrastructure for the science park with very limited financial assistance from the central government. In 1983, fourteen sites were selected by MITI. By 1990, this list grew to twenty-six, few of which are in the poorest regions. This limits the program's usefulness in equalizing regional resources.

Impressed with the potential of high-technology-led development, many newly industrializing countries (NICs), or aspirant NICs, have developed science parks. Parks in countries such as Singapore, Taiwan, South Korea, Hong Kong, and China have been initiated normally through direct government promotion. The Singapore government, for example, has a $2 billion national technology plan (for 5 years) beginning in 1991 ("Singapore Government Commits to R&D Growth" 1992). This money is set aside to facilitate industry-driven R&D by providing inputs such as training, scholarships, and foreign recruitment that the private sector is unable (or unwilling) to provide. The government provides tax breaks, grants, financial incentives, and infrastructure to encourage R&D by the private sector (domestic and international). The R&D expenditure in the one-million-square-foot science park totaled $86 million in the 1990-91 fiscal year. Private sector interests (mostly foreign-owned multinational corporations [MNCs]) accounted for about 60 percent of the park's tenants. The Singapore government hopes to upgrade the country's knowledge base and skill level, especially by improving knowledge of process R&D through increased interaction with the MNCs. The ultimate aim of the government is to improve the country's competitiveness in international export markets.

To summarize the origins and development of science parks, after a slow start, the concept took off in the 1980s and science parks were developed all over the world. Although their growth and development have varied by country and by case, all science parks appear to be based on the common belief that rapid economic growth is possible through high-technology-led development. Among the factors that have been important for the successful development of science parks are (1) appropriate state and federal policies that promote science parks, (2) establishment within or adjacent to existing urban agglomerations, (3) proximity to high-quality residential environments, (4) a preexisting culture of innovation, (5) proximity to at least one major university, (6) existence of high-quality infrastructure and communication and transportation networks, (7) an existing pool of skilled labor, (8) presence of at least one major firm in the park, (9) availability of venture capital, (10) spin-offs from existing firms, and (11) job mobility. Although a combination of these factors provides the optimum conditions for the successful development of science parks, the examples examined thus far demonstrate that in practice this seldom occurs.

RATIONALE FOR THE ESTABLISHMENT OF SCIENCE PARKS

As demonstrated earlier, there is no singular rationale for the establishment of science parks beyond the belief that it is a good vehicle for promoting economic growth at both the national and regional level. Different countries and regions have developed different conceptions of how science parks can best promote economic growth. For example, Japan sees science parks as a way of promoting regional equality; Singapore views them as a way of promoting national technology-led development; and regions in the United States and the United Kingdom often have seen them as a mechanism to overcome the collapse of traditional economic sectors. This fuzziness, perhaps, is what accounts for their popularity with policymakers, who often see science parks as a panacea for solving a wide range of divergent economic, social, and development problems. Policymakers hope science parks will cure economic problems by providing employment, generating regional multipliers, promoting exports and foreign investment, increasing the R&D capacity of the country, promoting technology development, and increasing investment. They also look to science parks to promote regional equality, upgrade the skills of the local workforce, increase revenue to the university, and perhaps even improve the mental health of those employed in the tranquil surroundings. Although this assessment may seem cynical, it reveals two underlying issues: first, it raises the question of the degree to which science parks can deliver on some of these expectations. Second, it points to the deep underlying malaise that affected the regional (and national) economies of most of the world during the 1980s and the restructuring movement that followed.

Monck et al. (1988, 73-78) identify a number of reasons why science parks were promoted in the United Kingdom during the 1980s: the collapse of many mature industries led to a rapid rise in unemployment; severe financial cutbacks in university funding forced institutions to look at other ways of increasing finances; new technologies, such as microprocessors, arose and increasingly matured; cutbacks in R&D spending by large firms led to the growth of small, high-technology firms; government policy shifted toward entrepreneurship; and banks offered improvements in services to small firms. Most of these reasons are equally applicable outside of the United Kingdom.

Goldstein and Luger (1989) offer two additional reasons for the development of science parks in the United States:

> First, there has been growing consensus among state and local policy officials and academics that a region's long-term economic prospects will depend on its ability to generate and sustain a concentration of business enter-

> prises capable of developing new products (or processes) than can penetrate international markets.... Fearing that they only would be able to attract "loser" industries, state and government officials sought ways to stimulate productivity growth and innovation in the existing industries and to generate new business in the high-technology sector. These officials believed that science park development could help them achieve those objectives.... The second reason for the widespread adoption of science parks during the past five to 10 years has been the worldwide publicity given to . . . Silicon Valley and the Research Triangle of North Carolina. Both of these US regions experienced considerable growth in the 1979-82 period while much of the rest of the United States suffered through a severe recession. (P. 5)

It seems in many cases, however, that policymakers had no clear idea of what they hoped to achieve by promoting science parks. The economic coordinator of Bradford City Council (U.K.) commented that the council had very little idea what they were getting themselves into when they decided to have a science park in Bradford: "no in depth studies, no academic research, just an idea. Let's have a Science Park in Bradford" (Massey et al. 1992, 21). Such lack of clarity over goals makes an evaluation of the performance of science parks rather difficult to measure; nevertheless, we attempt to do so in the following section.

EVALUATING THE PERFORMANCE OF SCIENCE PARKS

The performance of science parks can be evaluated in two ways. The first is to examine the degree to which an individual park is successful in itself. This success is usually measured in the number of firms or employees in the park, vacancy rates, turnover rates, and profits. A second and more fundamental way of evaluating performance is to measure success against some form of externality—increased employment in the region or increased exports out of the region, for example. What is crucial in an evaluation of science parks is the degree to which these benefits at the local level generate national growth. It is difficult, therefore, to abstract developments at the regional level from their effects at the national level. Moreover, these two types of evaluation are linked, and it is difficult to distinguish between their impacts. Nevertheless, policymakers (as opposed to developers) have focused on the second type of evaluation and the impacts on regions and the nation.

The two most ambitious attempts to use science parks as part of a national development strategy for regional development have been the Technopolis Program in Japan and the French technopole strategy. Hall (1991) sees both of these attempts at decentralized development and regional equality as conspicuous failures. He maintains "that all evidence to date seems to indicate that the genesis of innovative milieux is a highly elusive process, not readily subject to deliberate planning" (19). Glasmeier (1988) reaches a similar conclusion with regard to the Japanese Technopolis Program. She argues that too many sites have been designated as technopolises for the program to succeed. This "bandwagon effect" reflects the political difficulties that governments have in excluding particular regions. She also points out that preexisting industrial and social agglomerations are likely to be a greater factor in influencing firms in their site selection than are incentives given at the technopolis sites.

In a generally favorable review of the Technopolis Program, Masser (1990) examines the experience of the Nagaoka Technopolis. In his view, this technopolis has been relatively successful, and he estimates that forty new firms were attracted to the area within a five-year period. The population in the technopolis zone increased from 180 thousand to 631 thousand, and the local economic base (measured in terms of the value of industrial shipments) increased from 227 billion yen in 1980 to 1,116 billion yen in 1988. Masser points out that a key reason for Nagaoka's success has been the availability of serviced industrial land within easy access of Tokyo—just over a 90-minute train ride away. He concedes, however, that the area was having difficulty attracting key personnel by 1988 and recommends that more case studies be examined before any definitive conclusions can be made about either Nagaoka's experience or the success of the Technopolis Program can be made.

In her study of the Technopolis Program, Markusen (1991) questions whether high-tech activity can ever be decentralized. She argues that, at best, there is only a modest amount of detachable high-tech production—and even R&D activity—that can be relocated to peripheral sites. She also comments that the total number of "technovilles" a country can support is as important a consideration as where they should be located.

Markusen (1991) does not believe that Japan's Technopolis Program has staved off the continued concentration of economic activity in Tokyo or spawned new independent and self-sustaining centers of innovation; she does argue that the policy has altered the developmental landscape in Japan in a number of ways, however. First, it has institutionalized the competition between prefectural governments for industrial and research satellites—resulting in the weakening of emphasis on previous prefectural priorities such as improving the quality of life and environmental concerns. Second, the policy has set out a vision of exurbanized economic activity as a blueprint for future Japanese development and promoted a few pioneer cases as prototypes. These peripheral sites have not taken on the character of the locality and remain artificial re-creations of a suburban form of residential and work space familiar from the outer areas of Tokyo. Third, the policy manages to package a program of regional development as a national initiative without making any substantial financial commitment (most of which is borne by the prefectural governments themselves). Further, the tax breaks provided by the prefectural governments hamper the revenue-raising capacity of the prefectures to provide for social services and future infrastructure. Fourth, the investment on the part of the prefectures is highly speculative—reproducing in regional space a public sector version of the land speculation that drove, and subsequently ruined, the real estate market in Tokyo and Japan in general. Finally, the Technopolis Program has kept some Japanese companies from relocating to other countries by giving them incentives to relocate to cheaper areas within Japan itself. Markusen (1991) concludes that the Technopolis Program may succeed in decentralizing the less innovative components of high-tech activity in Japan but that it is unlikely to contribute to regional equalization of incomes because the growth will be concentrated heavily in a few locales.

Similarly, Jowitt (1988) is skeptical of the chances of science parks promoting regional development. He aptly quotes the remarks of a recent commentator:

> "[There are] symptoms of panic . . . in the present scramble by local authorities, by quasi-public agencies and by the public sector to make a Disraelian leap in the dark for the science and technology shore. Indeed, those parts of the UK most affected by economic decline . . . are . . . clutching at high technology, more particularly science and technology parks, as their sole panacea for future survival . . . the point is lost that without the support of a genuine regional economic planning framework they have no future—the market is working too strongly against them." (P. 135)

Jowitt also argues that only the better off regions stand any chance of promoting high-technology-led development. In the less competitive regions, he proposes that economic development be premised on a diversified economy based on a slimmed-down and technologically assisted manufacturing base; the continued development of the service sector, especially by expanding tourist and leisure services; and a small dash of high-technology. The appropriateness of such advice would seem to be dependent on the region under review.

Jowitt (1988) is undoubtedly correct in noting that there are definite national costs in pursuing high-technology-led growth in too many regions at once or in lagging areas. The competition among regions for sites can be expensive and wasteful, and the better-off regions always win. Further, incentives and subsidies provided by both national and local governments are generally self-defeating from a national perspective. As Addleson and Tomlinson (1985) argue, if a region or business has to be subsidized to survive, then the "value added" in production is negative. In other words, the value of its inputs taken out of the economy is greater than whatever it puts back into the economy. To sustain this situation, resources have to be drawn from other areas and reallocated to the subsidized region. With the redistribution of resources (and incomes) there is a corresponding decline in activity and employment in those areas from which resources were drawn. It would, therefore, seem that science parks should be promoted only in areas that do not require state or local government support in excess of the benefits they can provide. Goldstein and Luger (1991) make the point that

> Those regions in greatest distress that potentially could benefit the most from the presence of a viable research park (that is, through manufacturing job creation via forward linkages, productivity enhancement via technology transfer and diffusion, and overall wage increases in the local labor market) are also where research parks are not likely to be feasible. These include older manufacturing regions and nonmetropolitan areas without an existing R&D concentration. (P. 48)

It is precisely the areas Goldstein and Luger identify as having the least chance of establishing successful science parks that have touted science parks as a way out of their current economic malaise. Further, it is argued by Massey and Wield (1992) that these less fortunate regions have to offer substantial incentives to the private sector to entice them into setting up science parks:

> The public sector in this context classically takes the enterprising, risk running role usually ascribed to entrepreneurial (private) capitalism. The result is that public money from local taxes is used to subsidize profits made through property investment by financial institutions. But, as if this were not enough, there is also a further result in that the aims of the science park for the agents involved in the partnership of its development are, of course, very different. Although the private sector's aim is to make a profit, the aim of the public sector is local economic regeneration. The effect of public-private partnership, however, is that the aims of the public sector are inexorably subordinated to those of the private sector. (P. 420)

Although the universal application of their argument with regard to public-private partnerships is in need of further investigation, there is little doubt that the contradiction that Massey and Wield highlight is likely to be an important impediment to the success of science parks as a policy tool in many declining or stagnant regions. Given all the above, science parks do not qualify as a viable development strategy for most regions (Goldstein and Luger 1990).

When examining the regional impacts of science parks, it is essential to consider whether science parks promote new firm formation, and whether the types of firms attracted to science parks promote regional development. Monck et al. (1988) emphasize that

> to demonstrate the benefits [of a science park], it has to be shown not only that, for example, firms have established in the park, but that these firms either would not have been established if the park had not existed, or that they would have had to locate elsewhere—and that the alternative location would have imposed costs upon the firm in such a way as to impair its performance. (P. 89)

Such benefits are notoriously difficult to measure. Nevertheless, Monck et al. attempt to do so, arguing that the growth of science parks in the United Kingdom has led to the formation of more high-technology firms than would otherwise have been the case. A UKSPA survey found that two-thirds of U.K. science park establishments previously had been located elsewhere (Massey et al. 1992). Although this number is not insubstantial, Massey et al. argue that it does not wholly corroborate the popular image of science parks. Malecki (1991) takes a substantially similar view, arguing that parks themselves do not increase the propensity of new firms to form.

The case of Research Triangle Park confirms Malecki's point. Despite its reputation, Research Triangle Park has not been an unqualified success. Unlike more spontaneous developments such as Silicon Valley, the park's growth has occurred largely through attracting new firms from outside the region rather than through new-firm formation or spin-offs. Goldstein and Luger (1991) estimate that 47 percent of R&D organizations in the park probably would not have located in Raleigh-Durham if Research Triangle Park did not exist, and they argue that the park has had a substantial positive economic impact on the immediate region (Durham, Orange, and Wake counties). They estimate that "the total number of jobs in the region for which Research Triangle Park was responsible—that is, that would not be in the region if the park had not been created—is estimated to be 52,000. This represents 12.1 percent of the total regional employment in 1988" (88). They also found that the park helped increase the region's per capita personal income and decrease income inequality in the region. In contrast, studies of the counties affected by the Stanford Research Park found an increase in regional income inequality from the mid-1960s, although there is no hard evidence linking the park to this decline (see Goldstein and Luger 1991; Saxenian 1984). Further, according to Goldstein and Luger (1991), Research Triangle Park and new business growth within the region have provided jobs disproportionately to professionals and managers, although they comment that there is no evidence that any other occupational groups are worse off because of the park. Vogel and Larson (1985, 261) note, however, that Research Triangle Park has had only a modest impact on the state as a whole and that very few ripple effects have been felt outside of the region. According to 1990 U.S. census data, 1989 wages within the state were 85.6 percent of the national average in 1989, and per capita income was 86 percent of the national average. Goldstein and Luger (1991) argue that the potential of Research Triangle Park to achieve statewide economic development depends on the ability of state government and local school boards to improve the overall educational and skill levels of the non-university-trained labor force of the state:

> The expectation that the manufacturing production facilities of high-tech corporations will be induced to locate in other parts of the state in order to have good access to the R&D activity in the Triangle region, a major premise for the creation of the Research Triangle Park, just will not materialize until the state has a labor force that is capable of operating and maintaining increasingly sophisticated equipment in the new knowledge-based economy of the 1990s and beyond. (P. 99)

This is equally applicable to other areas with similar skill and development profiles.

The types of firms attracted to science parks are often unsuited for promoting regional development. Most science parks attempt to attract as many firms devoted to R&D as possible. In her analysis of Japan's Technopolis Program, Glasmeier (1988) argues that the focus on R&D establishments is not likely to lead to integrated or propulsive industry-led growth. She comments that high-technology establishments behave like other manufacturing enterprises and thus develop few local linkages. This skepticism of R&D as a propulsive industry is shared by Oakey (1991), who maintains that there is a weak link between R&D investment and a commercially successful product and that there is no correlation between R&D investment, turnover, and employment growth. Goldstein and Luger (1990) are less emphatic about this relationship, arguing that the level of activity from R&D depends on the size of the firms in the park: spin-off activity is higher when the park has a larger proportion of relatively new, small and medium-sized firms rather than R&D branches of large multilocational firms. As such, the recruiting policies of the park play a very important role in setting the conditions for regional growth. Goldstein and Luger (1989) note, however, that science parks located in regions with a prior concentration of R&D activity are more likely to be successful than those locating elsewhere.

The degree of interaction between universities and firms in science parks has been overestimated by policymakers. In a study of sixteen Australian science parks, Joseph (1989) concluded that the level of interaction among firms within the parks was low, as was their interest in research. Joseph also found little contact with the universities—a finding supported by MacDonald (1987) and Currie (1985). In his study of science parks in the Cambridge area of the United Kingdom, Keeble (1989) found that over one-half of all firms presently maintained, or had maintained, links to the university. This does not, however, indicate the degree of closeness that many policymakers and developers believe exists. Although the links between tenants of science parks and universities is a matter of dispute, it is clear that in most cases a university has been beneficial in attracting tenants to the parks. Goldstein and Luger (1991) argue that parks owned or operated by universities are more likely to generate growth than are parks with less formal links to universities. The results of their research also indicates that regions with parks that also contained research universities had better employment growth than those that did not.

When considering the impact of science parks on both national and regional development, it is important to recognize that their success rate does not appear to be high. A 1983 study of science/technology parks in the United States found failure rates of 50 percent (Joseph 1989). Although this percentage may be disputed, there is little doubt that the policy of promoting high-technology-led economic development must be viewed as a long-term process rather than the quick fix that many local governments and developers have made it out to be. The most successful parks, such as Research Triangle Park and the Cambridge Research Park, took more than a decade to become really viable. Goldstein and Luger (1991) suggest that the probability for success is far greater for older parks than those of more recent vintage. They comment that when it comes to the establishment of successful research parks, "the early bird gets the worm" (74). This implies that for many areas, especially in the United States, the chances of new parks being successful are not great. Malecki (1991) concludes that science parks

> are an attractive but highly uncertain policy. They often present little more than a theme for real estate or property sales and occupancy. This may attract some firms, but parks themselves do not increase the propensity of new firms to form. . . . It is not surprising then, that so few science parks in the USA and elsewhere have been successful, nor that the most successful are in large urban areas. . . . Given the "right" conditions, however, science parks can add measurably to regional economic development. (P. 310)

Although Goldstein and Luger (1991) do not differ on the whole from Malecki's conclusion, their study offers a more positive evaluation of the contribution of research parks to regional economic growth. They measured success by looking at "the difference in total employment growth rates—both after and before a park had been established—between counties with a research park and a control group of counties (without a park) having the same metropolitan status, population size, and location as the counties containing research parks" (59). Of the forty-five research parks they studied, thirty-two were situated in counties that grew faster than did their control group counties in the years after the parks were established. They advise caution when analyzing these findings, however, because they looked only at the employment growth rate for the first five years after park creation; and, because they could not control for all conceivable rival factors, they almost certainly classified some parks as successful whose counties would have grown relative to their respective control groups even without a research park.

We argue that two crucial determinants enhance the chances for successful science parks: state or government policy and location (see also Amirahmadi 1992). Successful science parks received fairly large degrees of either local or national government assistance. This assistance has taken diverse forms, from direct state subsidies in Singapore to the provision of infrastructure in North Carolina. Although government assistance is essential to the success of these parks, it is clear that both local and national policies to promote science park development have drawbacks. National policies, like Japan's, are open to abuse as politicians try to curry favor in various regions. The often vicious competition among regions to attract firms is costly to all—the region that wins, the regions that lose, and the country as a whole. A well thought-out national technology plan is more efficient than a piecemeal competition between regions. The Singapore approach of using science parks to advance the nation's human resources, increase its technological edge, and improve its international competitiveness is a case in point—although it is still too early to judge the success of this approach.

Location refers to the park's proximity to either existing urban agglomerations or to particular urban features—namely, a high-quality infrastructure, such as good transportation linkages (including proximity to an airport); a high-quality residential environment; a university; and a pleasant work environment. Given their importance to a park's success, it is not surprising that most publicity brochures for science parks highlight these features (see for example, *Equitable Real Estate* 1991). Malecki (1991) concurs with this view:

> Only metropolitan regions and their bundle of amenities and infrastructure are even potential locations for new firm formation. The complex and dynamic advantages associated with urban size—face-to-face communication, pools of workers or potential to attract and keep them—outweigh the largely aesthetic attributes of a science park. Policies have been unable to create the critical mass necessary to attract and keep professional workers, except in large urban areas. (P. 310)

The success of science parks has been mixed. Research Triangle Park, for example, has provided employment to skilled graduates and attracted firms into the region, but this success has come at a hefty cost to the state. Perhaps more important, the benefits have not been shared by either the bulk of the state's workforce or the region as a whole. These parks also offer no guarantee of promoting high-technology-led economic growth, at either the national or regional level. To do so, they must generate greater multipliers, more spin-offs, and more linkages with the surrounding areas.

CONCLUSIONS

Although the concept of science parks has merit, it is not the panacea for development that many policymakers and developers make it out to be. Many parks, including North Carolina's "successful" Research Triangle Park, have been established in areas that do not conform to most of the factors considered ideal for science park development. In such cases, only very generous state support and vigorous marketing have attracted tenants to the parks. At the regional level, the costs of such efforts often outweigh the benefits. Massey et al. (1992) make the point that investment in science parks actually contributed to increased regional inequality in the United Kingdom. Because the greatest chances for successful science park development are in the most advanced parts of a country, this is not an issue that can be lightly dismissed. As such, the question of whether science parks exacerbate regional inequality is an area deserving of further investigation.

A key assumption behind the promotion of science parks is that a concentration of R&D leads to the development of a strong regional multiplier or that R&D is a propulsive industry. But, in general, the link between R&D investment and a commercially successful product is weak, and there is little correlation between R&D investment and employment growth. This raises a serious question about the utility of science parks in promoting both regional development and increasing the diffusion of new technology. Even when science parks have promoted local employment, the benefits have been shared unevenly. Further studies of whether the main multiplier effects from science parks are technologically or income-driven is of great importance. If income-driven multipliers predominate, as Massey et al. (1992) argue, then it is likely that science parks will contribute to regional income inequality rather than ameliorate it.

Science parks employ workers with relatively high levels of academic qualifications—the vast majority of whom are men (Massey et al. 1992). Yet, with the exceptions of Massey et al. (1991) and Goldstein and Luger (1991), the gender issue of science park employment is conspicuously absent from most of the literature. Massey et al. (1992) note that there is a clear gender issue that needs further investigation.

The value of science parks as successful vehicles for high-technology-led growth outside the major industrial powers is highly debatable. It is more likely that science parks in the NICs and other industrializing countries will replicate the Australian case in which multinational corporations moved into the science parks primarily because of the status attached to the park. In Australia, these firms developed few links with each other, with local firms outside the parks, or with local universities. In such circumstances, the benefits to the host country must be questioned—especially given the vast sums of money many governments such as Singapore, are spending on attracting these firms. The applicability of science park development for the NICs and for less developed countries has not been fully explored in the existing literature and needs further research.

Another area that could profit from further research are studies of the linkages between science parks and defense-related R&D. This issue is neglected in the literature and is likely to be crucial when considering the future prospects of science parks. There is also a need for comparative studies of science parks in different countries. A comparative study of the United States and the United Kingdom would be of particular benefit because these two countries have the greatest number of science parks and also have similarly high proportions of defense-related R&D.

Science parks in themselves are not the answer to promoting regional or national high-technology-led economic development. They are, however, one of the options available to policymakers as part of a well-thought-out and coordinated development strategy. Such a strategy must build on regional or national strengths rather than artificial supports for costly and uncertain high-technology strategies. Yudken and Black (1990) suggest that these strategies should target national needs and then the federal government should devise policies that mobilize market resources to confront critical social needs. They recommend that these policies should (1) provide incentives for industries to conduct basic research; (2) improve technology transfer; (3) produce desired products; (4) support job training and education; and (5) maintain health, safety, and environmental standards (276).

It is possible for nations or regions to promote development within science parks at minimal fiscal cost. Government (state or federal) R&D facilities could be sited within selected parks, or government agencies could contract with firms located within the parks. Because science parks often enjoy more locational and research advantages than do firms located outside of parks, this could be a good strategy for maximizing the benefits derived from government research expenditures. Incentives could also promote R&D linkages between firms located within the parks. Such policies should be directed at only a limited number of strategically sited science parks, however, so that the benefits accruing from the policy are not diffused. It is also important that planners undertake local microstudies of the regional economy and political culture to assess local attitudes toward state intervention. This will not only allow planners and policymakers to anticipate possible sources of opposition but will also allow them to tailor plans to fit individual regional circumstances.

Planners must recognize that a science park is not a cure-all for an ailing regional economy. To be successful, any planning policy that relies on a science park must have concrete policy goals for the park at the outset. The experience of the Bradford City Council, which promoted a science park with no clear understanding of what the park could achieve, must be avoided. Planners can play a key role in avoiding such experiences by undertaking the microstudies suggested above, reading the relevant literature, and advising policymakers accordingly. Such a course would not only increase the effectiveness of science parks as a policy tool but also allow for an easier appraisal of their performance by providing concrete goals against which to measure performance.

These are only preliminary suggestions, and they require further investigation. The focus for future research should be aimed at overcoming the gaps in the literature highlighted in this article and studying the mix of federal and state policies needed to create a viable national strategy for economic development. Such strategies should incorporate the use of science parks, where appropriate, but only with a clear understanding of their problems and limitations.

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REFERENCES

Addelson, Mark, and Richard Tomlinson. 1985. Decentralization. *Human Resources 1985-86, Leadership S. A.*, Special ed. 40-44.

Allesch, Jürgen. 1985. Innovation centers and science parks in the Federal Republic of Germany: Current situation and ingredients for success. In *Science parks and innovation centers: Their economic and social impact. See* Gibb 1985.

Amirahmadi, Hooshang. 1992. Science parks. *Abadi* 2, 6 (Fall): 66-71.

Botkin, James W. 1988. Route 128: Its history and destiny. In *Creating the technopolis. See* Smilor et al. 1988.

Currie, J. 1985. *Science parks in Britain: Their role for the late 1980's.* Cardiff: CSP Economic Publications.

Dyckman, J. W., and E. A. Swyngedouw. 1988. Public and private technological innovation strategies in a spatial context: The case of France. *Environment and Planning C: Government and Policy* 6, 4: 401-13.

Equitable real estate. 1991. La Jolla, Ca.: Torrey Pines Science Park.

Everhart, Jane S. n.d. University-related research parks teach reality a thing or two about development. Undated memo.

Fusi, Deborah S. 1991. Major new sites for science continue to spring up around the world. *Site Selection* 36, 3: 610-15.

Gibb, John M, ed. 1985. *Science parks and innovation centers: Their economic and social impact.* Amsterdam: Elsevier.

Glasmeier, Amy K. 1988. The Japanese Technopolis program: High-tech development strategy or industrial policy in disguise? *International Journal of Urban and Regional Research* 12, 2: 269-84.

Goldstein, Harvey A., and Michael I. Luger. 1991. *Technology in the garden: Research parks and regional economic development.* Chapel Hill: University of North Carolina Press.

———. 1990. Science/technology parks and regional development theory. *Economic Development Quarterly* 4, 1: 64-78.

———. 1989. Research parks: Do they stimulate regional economic development. *Commentary* 13, 1/2 (Spring): 3-9.

Hall, Peter. 1991. Three systems, three separate paths. *Journal of the American Planning Association* 57, 1: 16-20.

Hall, Peter, Michael Breheny, Ronald McQuaid, and Douglas Hart. 1987. *Western sunrise: The genesis and growth of Britain's major high tech corridor.* London: Allen & Unwin.

Hayes, Thomas. 1987. Triangle Park. *New York Times* 26 April, 12.

Joseph, R. A. 1989. Technology parks and their contribution to the development of technology-oriented complexes in Australia. *Environment and Planning C: Government and Policy* 7, 2: 173-92.

Jowitt, T. 1988. Towards Silicondale? Lessons from American experience for the Penine towns and cities. In *Local authorities and new technologies*, K. Dyson, ed. London: Croom Helm.

Kawashima, T., and W. Stohr. 1988. Decentralized technology policy: The case of Japan. *Environment and Planning C: Government and Policy* 6, 4: 427-39.

Keeble, D. 1989. High-technology industry and regional development in Britain: The case of the Cambridge phenomenon. *Environment and Planning C: Government and Policy* 7, 2: 153-72.

Kysiak, Ronald C. 1989. The impact of research parks on regional development. *Real Estate Financial Journal* 5, 2: 64-69.

Laffitte, Pierre. 1988. Sophia-Antipolis and the movement south in Europe. In *Creating the technopolis. See* Smilor et al. 1988.

Larson, Judith K., and Everett M. Rogers. 1988. Silicon Valley: The rise and falling off of entrepreneurial fever. In *Creating the technopolis. See* Smilor et al. 1988.

MacDonald, S. 1987. British science parks: Reflections on the politics of high technology. *R&D Management* 17, 1: 25-37.

Malecki, Edward. 1991. *Technology and economic development: The dynamics of local, regional and national change.* Essex, England: Longman Scientific & Technical.

———. 1986. Research and development and the geography of high-technology complexes. In *Technology, regions and policy*, J. Reese, ed. Totowa, N.J.: Rowman & Littlefield.

Markusen, Ann. 1991. Technovilles: Some research-oriented comments. In Proceedings of the International Seminar on Development Experience of High-tech Industrial Parks, T. Lee, ed. Sunabo, Korea, November 1991.

Markusen, Ann, Peter Hall, and Amy Glasmeier. 1986. *High tech America.* Boston: Allen & Unwin.

Masser, Ian. 1990. Technology and regional development policy: A review of Japan's Technopolis Program. *Regional Studies* 4, 1: 41-53.

Massey, Doreen, Paul Quintas, and David Wield. 1992. *High tech fantasies: Science parks in society, science and space.* London: Routledge.

Massey, Doreen, and David Wield. 1992. Science park: a concept in society, science and "space" (a realist tale). *Environment and Planning D: Society and Space* 10, 4: 411-22.

McQueen, Doug. 1988. Research parks. *Site Selection* 33, 6: 1451-60.

Monck, C.S.P., R. B. Porter, P. Quintas, D. Storey, and P. Wynarczyk. 1988. *Science parks and the growth of high technology firms.* London: Croom Helm.

Moore, B., and R. Spires. 1986. The role of high technology complexes and science parks in regional development. Organization for Economic Cooperation and Development Seminar on Science Parks and Technology Complexes in Relation to Regional Development. Venice, Italy. June 3, 1986. *See* Keeble 1989.

Nunes, John L. 1985. Western technology meets Eastern aesthetics. *Electronic Business* 11, 3 (February 1): 100.

Oakey, R. P. 1991. High technology industry and the "peace dividend": A comment on future national and regional industrial policy. *Regional Studies* 25, 1: 83-87.

Onda, Masahiko. 1988. Tsukuba Science City complex and Japanese strategy. In *Creating the technopolis. See* Smilor et al. 1988.

Perrin, J. C. 1988. A deconcentrated technology policy—Lessons from the Sophia-Antipolis experience. *Environment and Planning C: Government and Policy* 6, 4: 415-25.

Saxenian, Annalee. 1989. In search of power: the organization of business interests in Silicon Valley and Route 128. *Economy and Society* 18, 1: 25-70.

———. 1984. The urban contradictions of Silicon Valley. In *Sunbelt-Snowbelt: Urban development and regional restructuring*, Larry Sawers and William Tabb, eds. New York: Oxford University Press.

Scott, Alan. 1988. *New industrial spaces: Flexible production organization and regional development in North America and Western Europe*. London: Pion Limited.

Singapore government commits to R&D growth. 1992. *Scientific American* 266 (January): Special advertising supplement, 5-1 - 5-16.

Segal, N. S. 1988. The Cambridge phenomenon: Universities, research, and local economic development in Great Britain. In *Creating the technopolis. See* Smilor et al. 1988.

———. 1986. Universities and technological entrepreneurship in Britain: Some implications of the Cambridge phenomenon. *Technovation* 6, 4: 189-204.

Segal Quince Wicksteed. 1985. *The Cambridge phenomenon: The growth of high technology industry in a university town*. Cambridge, UK: Segal Quince Wicksteed.

Smilor, Raymond W., George Kozmetsky, and David V. Gibson, eds. 1988. *Creating the technopolis*. Cambridge, Ma.: Ballinger.

Tatsuno, Sheridan. 1988. Building a Japanese technostate: MITI's Technopolis Program. In *Creating the technopolis. See* Smilor et al. 1988.

———. 1986. *The technopolis strategy: Japan, high technology, and the control of the twenty-first century*. New York: Prentice-Hall.

Vogel, Ezra F., and Andrea Larson. 1985. North Carolina's Research Triangle: State modernization. In *Comeback: Case by case. Building the resurgence of American business*, E. Vogel, ed. New York: Simon & Schuster.

Yudken, Joel, and Michael Black. 1990. Targeting national needs. *World Policy* VII, 2: 251-88.