Technology Policies and the Growth of Regions: Evidence from Four Countries

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ABSTRACT. Since the 1980s, all industrialized countries have established technology policies aimed at increasing economic growth through the development of scientific and technical resources. Most technology policy initiates are at the national level and are predominantly concerned with levels of funding. This is a problem because high-tech industrial development is observed to be regional in nature and national technology policies do not explicitly pursue regional goals. This paper tests two hypotheses. First, that the different explicit and implicit technology policies have had a significant, although unintended, impact on the development of a special type of space, the high-tech regions. Next, that the spatial effects of government technology policy promote high-tech regions over other regions, although this influence is primarily of an implicit or unintended nature.

I. Introduction

> Attracting high-tech has become the only development game of the 1980s.
>
> Annalee Saxenian, 1985, p. 102

Beginning in the late 1960s, prevailing opinion recognized that technological progress, innovation and technology could be decisive determinants for both national and regional growth (NAS/NAE 1969, Thomas, 1975). Since that time, there have been many studies by regional economists and economic geographers which investigate the relationship between technological change and spatial development, specifically focusing on high-tech regions (e.g., Aydalot and Keeble, 1988; Bathelt, 1991; Breheny and McQuaid, 1987; Cappellin and Nijkamp, 1990; Castells, 1989; Castells and Hall, 1994; Hall and Markusen, 1985; Malecki, 1991; Markusen et al., 1986; Nijkamp, 1986; Rees, 1986; Scott, 1988).[1]

Despite the abundance of studies that deal with the genesis of individual high-tech regions, there are few comparative studies and few generalizable explanations exist. In particular, the influence of national and regional technology policies have never been systematically analyzed in spite of their widely assumed relevance. In addition, government funding of research and development favors different sectors in different countries (cf. Roobeek, 1990), and the consequences for high-tech regions are as yet unknown. Few attempts have been made to examine the influence that technology policies have on the development of high-tech regions. One area, albeit an exception, where significant literature does exist concerning the impact of government technology policies on high-tech regions is military spending on R&D (cf. OhUallacháin, 1987; Wells, 1987; Glasmeier, 1988; Markusen et al., 1991). A further research gap is the lack of generalization on the genesis of high-tech regions in different countries at different times. The same point can be made regarding the lack of combination of case studies on high-tech regions and the lack of comprehensive cross-sectional analyses (Thompson, 1989). Therefore, the main objective of this paper is to evaluate the influence of government technology policies on the development of selected high-tech regions in four leading industrialized nations. Moreover, this paper presents an empirical analysis of the connection between government spending on R&D and the high-technology intensity of regions in the U.S., Great Britain, Germany and Japan.

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II. Technology policies, regional growth and development theories and the reasons for the genesis of high-tech regions

The growing significance of technological progress for international competitiveness has accorded great importance to the technology policies of highly-industrialized nations during the 1980s (Ergas, 1987). Accordingly, the literature has considered cross-country comparisons of technology policy and the effects of technology policies on economic activity (Nelson, 1984; Roobeek, 1990; OECD, 1992; Scherer, 1992; Tyson, 1992).

Notably absent is a consideration of the relationship between technology policy and the growth and development of high-tech regions. The fact that the major industrialized countries do not pursue regional goals with their national technology policy may be partially responsible for the lack of attention to this issue. Most importantly, since many national technology policies are not explicitly concerned with regions, many policies have implicit effects that may be significant, although unintended, impacts on the development of high-tech regions. It does not matter if technology policies are oriented toward accomplishing specific projects as they are in the United States, Great Britain and France, or are oriented toward the diffusion of technology as they are in Germany and Japan.[2] Their regional impacts may not be intended or even considered in policy formulation. For example, government R&D expenditure may be allocated to specific technologies and programs but these expenditures are realized in regions where these technologies and programs exist. In this way, the growth and development of regions is affected. These regional impacts are usually unintended but their effects are substantial and are certainly not spatially-neutral.

There are a variety of ways in which government policy influences high-tech regions. In industrialized economies, technology policies are pursued by a variety of different ministries with various instruments and with varying means of implementation. Unfortunately, the policies of different ministries often have different goals and may produce conflicting, counter-productive effects. The agents who determine technology policy act at the local, regional, national and in the case of the European Union, the supra-national level. The effects are also felt at the respective lower policy levels. For example, in Germany the technology policy of the federal government affects the formation and realization of technology policy in the "Länder" and the cities. In general, technology policy is oriented toward existing technological competencies which impairs any efforts to achieve regional balance. For this reason, technology policy implicitly promotes agglomeration in high-tech regions at the expense of less-developed regions. As will be considered later, this may not be an undesirable outcome.

Figure 1 provides a diagram of the basic relationships between government policy and technology-based regional development. There are a variety of ways in which government policies have spatial effects. The effects are most tangibly observed in direct R&D expenditures, R&D contracts and the location decisions of government facilities. These policies, whether implicit or explicit can generate the emergence and development of high-tech regions. In addition to these effects technology policies may cause aspatial impacts in an implicit or explicit way. The – implicit – favor shown to large firms concerning federal R&D-contracts in the U.K. and (until the 1970s) in Germany is an example of this kind of effects (Rothwell, 1986; Bruder and Dose, 1986). The same is true for preferential treatment of specific branches (e.g., electronics) or technological fields suitable for military purposes (e.g., laser technology).

Seen from the perspective of a particular region, the relevant question is: which of these determinants will lead to intra-regional high-tech growth? Table I provides an assessment of several theories of regional growth and development. Each approach has specific strengths and weaknesses. The milieu approach, for example, convincingly explains the conditions under which innovation can occur (Aydalot and Keeble, 1988; Maillat and Lecoq, 1992). This theory provides an elaboration of the emergence of innovation – as does the related growth pole theory (Thomas, 1975; Hall, 1990). Unfortunately these theories offer little relevance for older technology-intensive products. In addition, the qualitative nature of these theories makes it difficult to measure their determinants. The latter stages of the life-cycle for

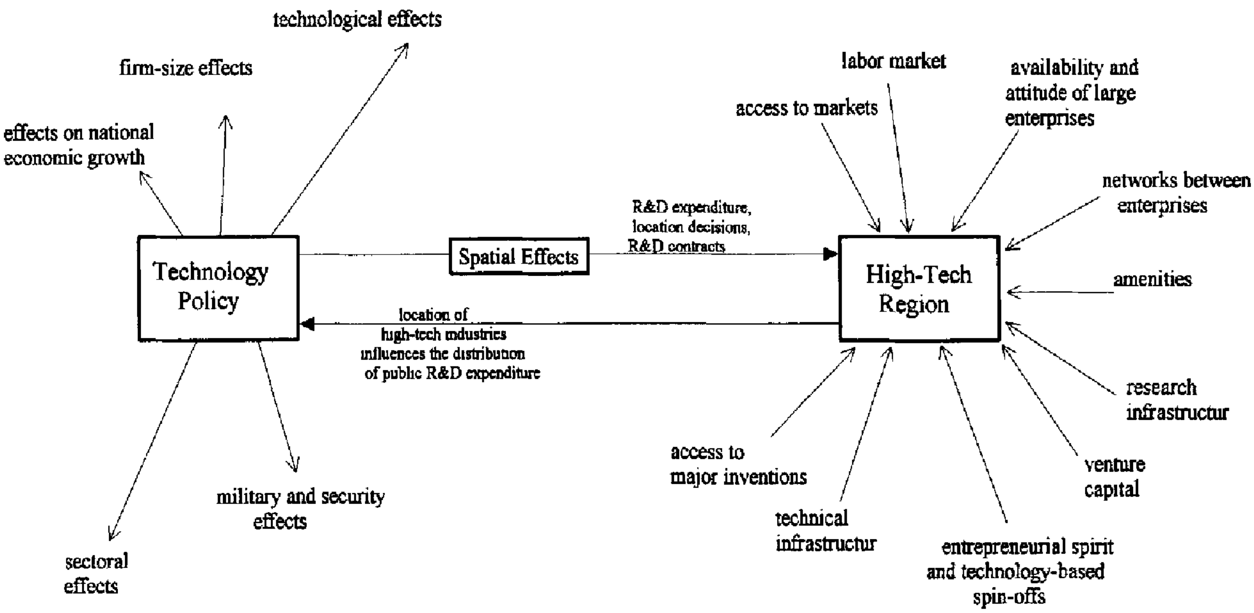

Fig. 1. Relationships between technology policy and high-tech regions.

TABLE I
Regional growth theories, high-tech regions, and technology policy

Theory	Applicability to regions		What is the relative information to be obtained from high-tech products and/or enterprises and/or regions regarding their		Consideration of technology policy instruments
	In general	Regional examples	Genesis	Growth	
Product Cycle Theory (regional version)	●	Southward and, later, westward migration of industry in the U.S.A.	○	●	○
Long Wave Theory	originally ○, later ●	British Standard Regions, U.S. federal x Regions, Northern Italy	●	○	○
Theory of Flexible Production and Specialisation, Industrial Districts	●	"Third Italy", parts of California, Baden-Württemberg	○	●	○
Innovative Milieus, Network Approach	●	So far very few case studies, mainly in France and (concerning production networks) in Silicon Valley	●	○	●
Locational Determinants Theory	●	Global application at all spatial levels	○	●	●

● = very appropriate, useful explanations; ○ = not appropriate, no useful explanations.

innovative products, which are particularly employment-intensive, are addressed by the regional variant of the product life-cycle hypothesis (Tichy, 1991; Rees and Stafford, 1986; Vernon, 1979). However, this theory says little about how and where the cycle begins. Presently, it seems that the theories of flexible production and specialization, and the related industrial district approach, most convincingly address the location behavior of innovative firms (Storper and Walker, 1989; Scott, 1988; Scott and Storper, 1990). Unfortunately, these theories are best in their description of locational factors and still lack empirical, measurable indicators. The location factor approach is limited since it does not explain but merely describes (Haug, 1991). The theory of long waves of economic development convincingly explain that the phases of growth have technological causes and are realized in different locations (Marshall, 1987; Hall and Preston, 1988; Freeman et al., 1982). This descriptive approach does not, however, address the questions of why and where and has limited predictive use and policy relevance.

Given the present stage of the development of theory on regional growth, Hall (1990) advocates an eclectic approach that combines the most convincing aspects of the above theories. Whether such an approach relies on a combination of the milieu approach and growth pole theory as advocated by Hall (1990) or a combination of the product life cycle hypothesis, growth pole theory and location factor analysis as suggested by Rees and Stafford (1986) may be debated. Pragmatically, the emergence and dynamics of high-tech regions are due to a multitude of interdependent causes which, to date, have not been adequately explained by a single theory (Peschel, 1989).

In addition, there are no theories that take into sufficient account the government's influence on the development of high-tech regions. The existing theories do not explain the difference between the factors that are unchangeable conditions and those which may be manipulated by policy (Thompson, 1989). For example, Hall's eclectic approach fails to explain the influence of military spending on high-tech regions (Hall, 1990). In conclusion, this review has revealed that no universally-valid and empirically-substantiated theory concerning the importance of technology policies for regional high-tech growth exists. With this background in mind, the next section provides a methodological approach for obtaining a comparison of the effect of governmental policies on high-tech regions in industrialized countries.

III. Methodological approach

In order to take into account the qualitative aspects of high-tech regions and to obtain results that are representative and empirically well-founded, this study will use a combination of methods. The first will be case studies of high-tech regions and the second will be a cross-sectional analysis.

To investigate the specific causes of the genesis of and the development into a high-tech region and to evaluate the role of technology policies, seven case studies were conducted in four industrialized countries. The case studies were chosen to represent different types of high-tech regions and are not necessarily the largest agglomeration or the most prominent in each country. The seven case studies are the Western Crescent, outside of London; the Munich region in Germany; the Research Triangle in North Carolina; Cambridgeshire in Great Britain; Silicon Valley in the U.S.; Greater Boston in the U.S.; and, Kyushu Island in Japan. The case study regions, without exception, are distinguished by a far above-average dynamic growth, but only the older regions are characterized by above-average growth level indicators.[3] The Western Crescent, west of London, and the Munich region in Germany have continuing high growth dynamics and represent the dominating high-tech regions of Great Britain and Germany (Hall et al., 1987; Sternberg, 1993; Castells and Hall, 1994). In contrast, the growth dynamics in Cambridgeshire in Great Britain and in the Research Triangle in the United States, do not belong to the high-tech centers in absolute standard but provide interesting policy examples and are much more dynamic than the regions mentioned above (Garnsey and Cannon-Brookes, 1993; Little, 1989; Bathelt, 1991). To date, the U.S. has the most intensively studied high-tech regions. Silicon Valley is considered the prototype of a high-tech region, and by absolute as well as relative growth criteria is the top technological center of the U.S. (Saxenian, 1994). Greater Boston also ranks as a growth region in what

Saxenian (1994) has identified as a key center in a long wave of economic development. The largest U.S. high-tech region, by absolute standards is the Los Angeles agglomeration (Scott, 1992) which is not included in this case study. The final case study is Kyushu, or Silicon Island, which was selected to provide an observation for Japan and is especially interesting because of an usually large number of enterprises in the semiconductor industry (Matsubara, 1992).

The second aspect of this study is a cross-sectional regression analysis of the determinants on high-tech employment for all subregions of a country. This method is used to find the specific determinants of the high-tech endowment of regions of a country, in both absolute and relative terms. Because the case study regions may not be typical of all regions of a country, this procedure considers the policy impact on jobs and businesses more generally. Moreover, due to rapid structural changes, today's "middle-tech" regions may become the high-tech regions of tomorrow. Therefore, a cross-sectional analysis for the regions within each country was conducted.[4] The independent variables used are the absolute number of high-tech employees and the proportion of high-tech employees for each region. The independent variables are derived from the previously-mentioned theories. In general, many of the theories indicate that an influence such as R&D expenditures would be important. In addition, to keep the number of independent variables manageable only one of several predictors with similar interpretation was used.[5] Table II presents the correlations between the determinants and the share of high-tech employment and the level of high-tech employment. The results are presented here are for 54 British counties but similar analysis was carried out for the U.S. and Germany.[6]

One difficulty in cross-country comparisons, and perhaps one reason why more of them do not exist, is the lack of uniform, or even comparable variable definitions and data availability. This study has tried to ensure that these difficulties were minimized in order to facilitate comparisons (Sternberg, 1995).

IV. Empirical results

A. *Causes of the emergence and dynamics of selected high-tech regions in the U.S.A., Great Britain, Germany and Japan*

An analysis of the genesis and development of the seven study regions reveals that not one single

TABLE II

Correlations between high-tech employment and explanatory variables in Great Britain[a]

Determinants	Expected sign	Dependent variables[b]	
		HTLQ 1989	HTEMP 1989
Net capital expenditure in manufacturing 1989 per employee	+	–0.108	–0.097
Gross value added in manufacturing 1989 per employee	+	+0.343*	+0.319*
Quality of education 1989/90	+	+0.257	–0.134
Number of Science Park tenants 1988	+	–0.059	+0.325*
Unemployment rate 1990	–	–0.455**	–0.191
Gross domestic product per capita 1988	+	+0.396*	+0.627**
Firm foundations in manufacturing 1980–1988 per 1,000 employees	+	–0.083	+0.015
R&D expenditure by MoD per capita 1990/91 (logged)	+	+0.624**	+0.661**
R&D expenditure by DTI per capita 1991/92 (logged)	+	+0.225	+0.286
R&D expenditure by MoD und DTI per capita (logged)	+	+0.644**	+0.607**
Number of R&D projects supported by the EC (logged)	+	+0.409*	+0.746**
Population 1990 (logged)	–	+0.032	+0.840**
Population change 1981–1990 in %	+	+0.167	–0.255
Supported by regional policy (Dummy)	–	–0.399*	–0.244

[a] Pearson coefficient of correlation; Significance ** 1%-level, * 5%-level.

[b] HTLQ89: share of employees in high-tech industries compared with all employees in manufacturing 1989 (location quotient); HTEMP89: total number of employees in high-tech industries in 1989 (logged).

determinant is universally important. As demonstrated in Table III, in the three American regions and in Cambridgeshire, the research and education infrastructure – a frequently quoted determinant – counts among the major influences. In the Western Crescent and in Kyushu research and education infrastructure is of hardly any significance. Amenities are often mentioned in connection with high-tech industrial development yet in most of the study regions they appear to have very little influence. It also appears that the importance of risk capital is also overrated. What is somewhat surprising is that the process of metropolitan decentralization and the presence of a key entrepreneur or scientist appears to be of greater importance than expected. For example, the growth of the Western Crescent is related to London in the same way that the Silicon Valley is related to San Francisco. It also appears that key individuals, such as Robert Noyce in Silicon Valley, are pivotal as catalysts in the development of these high-tech region.

Government R&D activity has a considerable effect on the regions. Malecki notes that it is difficult to make broad statements about government R&D and its effects on the economic performance of regional economies (Malecki, 1985, p. 125). This is, no doubt, true about high-tech regions because of the various mechanisms by which government R&D activity is allocated. For example, government R&D affects the quality of the research and education infrastructure in a region. It can also affect the availability of science and research parks and the availability of risk capital.

Table III reveals that all of the determinants corresponding to a state's technology policy, together with the R&D infrastructure are the main factors that affect the emergence and development of the seven regions. Direct or explicit influence manifests itself essentially in two forms. Government R&D expenditures for contract research at universities and in enterprises, or for state facilities have implicit regional effects since they are essentially oriented toward pockets of available resources. This fact is critical for young enterprises and industries which focus on technology intensive applications of scientific discoveries. This requires location near the site of these discoveries.

Following Gordon (1991), publicly-influenced high-tech regions can be divided into three types. First are state-led high- tech regions that are the results of explicit technology policy with intended regional goals. This propagates technology-based growth poles either in the form of new industrial spaces such as the Technopolis in Japan or Sophia Antipolis in Southern France, or in the form of a linkage of high technology and existing industrial potential, as in Sweden. The second type is a state-facilitated high-technology complex which endeavor to utilize the comparative advantages of their specific area on an international scale all the while receiving subsidies from the central and regional governments. Entrepreneurial target groups are, above all, multinationally operating combines attempting to profit from the advantages of lower wage costs. The Scottish high tech region "Silicon Glen" is the best known example of this type of influence (Sutherland, 1993). The third type are state-dependent high-tech regions where the political influence is indirect rather than direct. This kind of influence results from massive government investments and R&D expenditure especially in the military field, it does not, however, intentionally pursue regional goals (SRI, 1984). Due to the lack of local integration and the long-standing confidence in protected markets with monopolistic demand structures there is little or no innovative structural change and, consequently, in the long term, no international competitiveness. A good many of these characteristics can be found, e.g., in Los Angeles and the Western Crescent and some of them also in early Silicon Valley.

In conclusion, we obtain a regional model that resembles Porter's (1990) system of determinants of national competitiveness. The growth and development of high-tech regions is determined by interrelated production networks of large and small enterprises, by endowments of production factors such as qualified labor and risk capital, by the demand for new knowledge-intensive products and by entrepreneurial strategies and competition. At the regional level, it seems appropriate to add in a fifth factor to reflect both implicit and explicit technology policy.

TABLE III
Qualitative assessment of selected determinants of the genesis and growth of high-tech regions

Determinants	Silicon Valley		Greater Boston		Research Triangle		Western Crescent		Cambridgeshire		Munich		Kyushu
	Genesis	Growth	Genesis	Growth	Genesis	Growth	Genesis	Growth	Genesis	Growth	Genesis	Growth	Genesis
Research and educational infrastructure (and, therefore, availability of qualified labor)	●	●●	●●	●●	●	●●	○	○	●●	●●	○	●	○
Innovation Centers, Science Parks	○	○	○	○	●●	●	○	○	●	●●	○	○	○
Government policies (with explicit regional goals)	○	○	○	○	○	○	○	○	○	○	○	○	●●
Federal R&D-expenditure (with implicit regional impact, e.g., contract research)	●●	●	●●	●	●	○	●●	●	○	●	●●	●●	○
Technology policy of the region (with explicit regional goals)	○	○	○	○	●	●	○	○	○	○	●	●	●
Private demand for technology-intensive new products	○	●●	○	●●	○	○	○	●	○	○	○	●●	○
Public demand for technology-intensive new products (especially military demand)	●●	●	●	●	○	○	●	●●	○	○	●	●	○
Amenities (environment, culture, living conditions, etc.)	●	●	○	○	○	○	●	●	●●	●	○	●	○
Availability of large enterprises and their attitude toward small and young technologie-oriented firms, also intraregional production networks	○	●	●	○	○	○	○	○	○	●	●●	●	●
Location of major inventions	○	●	●	○	○	○	○	○	○	○	○	○	○
Availability of venture capital	○	●	○	●	○	○	○	●	○	○	○	●	○
Role of key persons	●	●	○	○	●●	○	○	○	○	○	●	●	○
Decentralization processes in large agglomerations (the opposite of endogenous development)	○	○	○	○	●	●●	●●	●●	○	●	○	○	●●

●● = the two most important factors; ● = important factor; ○ = less important or not relevant.

B. *General relations between high-tech employment and state R&D expenditures in the subregions of the U.S.A., Great Britain and Germany*

Table IV presents a cross-country comparison of the regression results. Because the lack of direct comparability of data across countries this table presents a summary rather than providing coefficients. Our interest is in the sign and significance associated with each determinant and not necessarily with the magnitude of the coefficient.

For all of the five countries, state R&D expenditures are positively correlated with high-tech employment, both the absolute number of employees and the relative share. In addition, the correlation with the economic power of the region is likewise very strong and positive. Also, as expected due to the relevance of agglomeration advantages, there is a strong statistical association between city size and high-tech employment. The results on population are more ambiguous since they correlate positively with the share of high-tech employment as expected, but are negatively related to the level of high-tech employment. The presence of science parks and innovation centers show non-uniform results, perhaps reflecting the great variation in the operations of these programs.

TABLE IV
Determinants of the number and share of employees engaged in high-tech industries in selected countries (comparison of correlation analyses)[a]

Determinants	Expected sign[b]	U.S.A.		Great Britain		Germany		Japan[e]
		Abs.[c]	Rel.[d]	Abs.[c]	Rel.[d]	Abs.[c]	Rel.[d]	
Population[f]	+		+		+		+	–
Population growth	+	–	+	–	+	–	+	
External control	–	–	–					+
Share of highly qualified labor	+					+++	+++	++
Patent intensity	+					+++	++	–
Firm foundations in manufacturing	+			+	–	+++	+	
Industrial innovations per employee	+	++	+					
Industrial age of the region	–					++	+	
Mean firm size	+/–	–	–			++	+++	
Mean wage rate in manufacturing	+/–	+	–					
Quality of education (universities, high-schools)	+	+	++	–	+	+	+	–
Availability of venture capital[f]	+							–
Amenities (environment, culture, living conditions, etc.)	+	–	+			—	–	
Public R&D expenditure per capita	+	++	+	+++	+++	++	++	
Public R&D expenditure for military purposes per capita	+	+++	+	+++	+++			
Science Parks (availability or number of tenants)	+			++	–	–	–	
Gross domestic product per capita)	+	++	++	+++	++	+++	+++	+
Unemployment rate	–	—	—	–	—	+	+	—

[a] The signs refer to the Pearson correlation coefficients and correspond to the following values: +++ = r > 0.5; ++ = 0.3 < r < 0.5; + = 0 < r < 0.3; — = –0.3 < r < –0.5; – = –0.3 < r < 0; an empty cell means, that there is no correlation coefficient due to lack of data.

[b] Expected sign according to the above-mentioned regional growth theories.

[c] Absolute number of employees in high-tech industries.

[d] Share of employees in high-tech industries (compared with all employees in manufacturing).

[e] In Japan the degree of achievement of the "Technopolis" sites serves as independent variable (as of 1989), the simple majority of the three variables used there is decisive.

[f] Because of size effects with these variables their correlation coefficients with the absolute number of employees in high-tech industries have not been used.

V. Final remarks

Using two complementary methodologies, this paper has demonstrated that there are a specific set of determinants which account for high-tech regional development. In the seven selected case studies, the unintended spatial effects of R&D expenditures played an important role, especially in the early stage of technology-oriented growth. Obviously, there is a fundamental correlation between the age of the region – the time elapsed since high-tech industries became established and the impact of state policies. In relatively young regions, such as the Silicon Valley in the late 1950s and the 1960s, in the Research Triangle in the 1970s or in Kyushu at present, policies have a greater impact. In more established high-tech regions, by contrast, commercial markets gain importance and the significance of government R&D is reduced.

Figure 2 provides a cross-sectional and a longitudinal analysis of the relationship between the impact of technology policy and the age of the high-tech region. It seems to be clear that there exists a general and negative correlation between both variables. The impact of technology policy is relatively strong during the early phase (took-off-phase) of a high-tech region, e.g., the Silicon Valley of the 1950s or Kyushu of the 1990s. On the other hand for matured and very large high-tech regions state technology policies represent, at best, only a less important determinant of regional growth.

The regression analysis for all subregions of the four countries from which the case studies were drawn reveals some striking parallels to the findings from the case studies but also some notable differences.

What technology policy conclusions may be drawn from this investigation? The answer to this question is confounded by the fact that the unintended effects of technology policy appear to be an essential determinant in the genesis and development of high-tech regions. Paradoxically, not only is the regional impact of R&D activity unintended, it actually contradicts the explicit policy goals of Great Britain and Germany of aiding lagging regions. Increasingly, there is an orientation toward favoring backward regions and although high-tech growth may be intended for

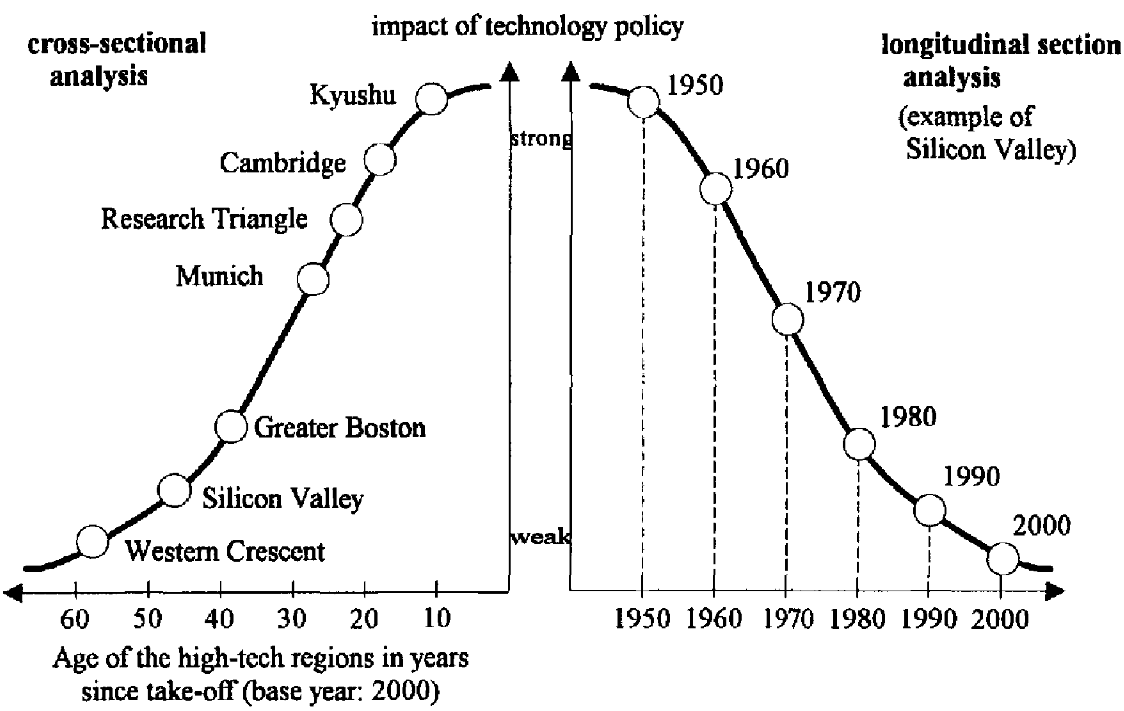

Fig. 2. Relationship between the impact of technology policy and the age of the high-tech region.

these regions, it seems unlikely. Too many other requisite factors may be lacking.

Selective government promotion of already growing high-tech regions would not be compatible with the goals of regional policies of national governments in industrialized countries. Policies aimed at the spatial development are limited to the periphery, forexample, Sophia Antipolis in France, or are aimed at rejuvenating older industrial regions. In contrast, the promotion of dynamic, although not yet internationally-competitive, high-tech regions has not been an official policy in any of the industrialized countries. This is surprising because national competitiveness not only depends on the competitiveness of individual industries but also depends on the vitality of a country's high-tech regions (Porter, 1990).

It should be noted that inter-regional disparities would increase if the above strategies were pursued. The policy choice is between the lesser of two evils – trading off between building high-tech regions and increasing international competitive advantage, and increasing inter-regional disparities between growing and lagging regions. To date, policy has always been in favor of balanced regional growth. It should be noted that policy oriented toward promoting R&D intensive firms in peripheral and lagging regions has not been very successful. This is to be expected since R&D is only one of the factors affecting the development of a high-tech region. If other factors are missing then we might not expect to that government R&D expenditures will be sufficient to promote industrial development (Feldman, 1994).

In view of the increasingly unrealistic target of balanced material living conditions in a country, it seems that future policy might focus on building the strengths of emerging high-technology regions. In countries that have achieved the economic scale of Great Britain, Germany or Japan, the idea of a spatial division of labor while accommodating technological inter-regional disparities warrants consideration. Within such a spatial division of labor, it would desirable to build up internationally-competitive high-tech regions through intended policy. The competitiveness of these regions would benefit peripheral regions where technology-based growth is less-likely or can be generated only with high expenditures. Such an economic development strategy, indeed, in an era of fiscal contraction, may produce the most cost effective policy.

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Notes

[1] For the purpose of this discussion, high-tech regions are characterized as having a high proportion of employees and/or plants in sectors that are classified as "high-tech" in the respective countries. There is little agreement, even within one country, about how to define "high-tech" (for the U.S.A. cf. Thompson, 1988b). This study utilizes high-tech lists specific to the individual countries; they were taken from the literature (for the U.S.A. cf. Thompson, 1988a, for Germany cf. Legler, 1992, and for Great Britain cf. Butchart, 1987). First, there are no internationally applicable definitions of high-technology at the level of economic sectors. Lists of high-tech products are internationally in use but do not help much, since for purposes of comparison they would have to be adjusted to fit the economic sectors; as the national systems differ greatly, this would be an impossibility. Second, national lists better reflect the comparative strengths of the individual states in the area of high technology. For example, an industrial branch can be considered technology-intensive by international standards in

one country and not in another. Since this paper deals with high-tech regions of individual states (not necessarily at the international level), national high-tech lists are more accurate.

[2] This statement reflects the difference between "mission-oriented" versus "diffusion-oriented" technology policies according to Ergas (1987) and Chiang (1991). The mission-oriented approach can be characterized as an attempt to generate and exploit radical innovation. It tends to emphasize effort in big science and technology and programs, which are concentrated in defense and aerospace. By contrast the diffusion-oriented policy tends to concentrate on diffusion and assimilation of technology in industry and market-pull plays a greater role in this kind of strategy.

[3] Dynamic growth indicators are defined, for example, by the growth rate of gross domestic product per capital or by the growth rate of employment in high-tech sectors. The indicators for the growth level indicator are static ones like, for example, the proportion of employees in high-tech sectors in all employees in manufacturing compared with the respective value of the nation (location quotient).

[4] For the United Kingdom the author was not able to obtain data concerning the R&D-expenditures of the Ministry of Defence for the ten counties in Scotland and for Northern Ireland; therefore the analysis is restricted to the 54 counties in England and Wales.

[5] The analysis uses all of the regions for which data are available. This omits some of the small regions which are subject to data suppression.

[6] The case study of Japan revealed that the explicit policy of creating high-tech regions, or Technopolis, is at work (Glasmeier, 1988; Stöhr and Pöninghaus, 1992; Castells and Hall, 1994). Therefore, the author's analysis of Japan focused on the 26 technopolis zones.

References

Aydalot, Philippe and David Keeble (eds.), 1988, *High Technology Industry and Innovative Environments: The European Experience*, London/New York: Routledge.

Bathelt, Harald, 1991, 'Employment Changes and Input-Output Linkages in Key Technology Industries: A Comparative Analysis', *Regional Studies* **25**(1), 31–43.

Breheny, Michael and Ronald McQuaid (eds.), 1987, *The Development of High Technology Industries: An International Survey*, London/New York/Sydney: Croom Helm.

Bruder, Wolfgang and Nicolai Dose, 1986, 'Forschungs- und Technologiepolitik in der Bundesrepublik Deutschland', in Wolfgang Bruder (ed.), *Forschungs- und Technologiepolitik in der Bundesrepublik Deutschland*, Opladen: Westdeutscher Verlag, pp. 11–75.

Butchart, Ron, 1987, 'A New U.K. Definition of the High Technology Industries', *Economic Trends* **400**, 82–88.

Cappellin, Riccardo and Peter Nijkamp (eds.), 1990, *The Spatial Context of Technological Development*, Aldershot: Avebury.

Castells, Manuel, 1989, *The Informational City. Information Technology, Economic Restructuring, and the Urban-Regional Process*, Oxford/Cambridge: Blackwell.

Castells, Manuel and Peter Hall, 1994, *Technopoles of the World*, London/New York: Routledge.

Chiang, Jong-Tsong, 1991, 'From "Mission-oriented" to "Diffusion-oriented" Paradigm: The New Trend of U.S. Industrial Technology Policy', *Technovation* **11**, 339–356.

Ergas, Henry, 1987, 'Does Technology Policy Matter?', in Bruce R. Guile and Harvey Brooks (eds.), *Technology and Global Industry. Companies and Nations in the World Economy*, Washington: National Academy Press, pp. 191–245.

Feldman, Maryann P., 1994, *The Geography of Innovation*, Dordrecht/Boston/London: Kluwer Academic Publishers.

Freeman, Christopher, John Clark and Luc Soete, 1982, *Unemployment and Technical Innovation. A Study of Long Waves and Economic Development*, London: Pinter.

Garnsey, Elizabeth and Andrew Cannon-Brookes, 1993, 'The "Cambridge Phenomenon" Revisited: Aggregate Change among Cambridge High Technology Companies since 1985', *Entrepreneurship and Regional Development* **5**, 179–207.

Glasmeier, Amy K., 1988, 'Factors Governing the Development of High Tech Industry Agglomerations: A Tale of Three Cities', *Regional Studies* **22**(4), 287–301.

Gordon, Richard, 1991, 'Innovation, Industrial Networks and High-Technology Regions', in Roberto Camagni (ed.), *Innovation Networks: Spatial Perspectives*, London/New York: Belhaven Press, pp. 174–195.

Hall, Peter, 1990, *The Generation of Innovative Milieux: An Essay in Theoretical Synthesis*. Working Paper 505, Berkeley: Institute of Urban and Regional Development, University of California.

Hall, Peter and Ann R. Markusen (eds.), 1985, *Silicon Landscapes*, Boston: Allen & Unwin.

Hall, Peter et al., 1987, *Western Sunrise*, London: Allen & Unwin.

Hall, Peter and Paschal Preston, 1988, *The Carrier Wave. New Information Technology and the Geography of Innovation, 1846–2003*, Boston/Sydney/Willington: Unwin Hyman.

Haug, Peter, 1991, 'The Location Decisions and Operations of High Technology Organizations in Washington State', *Regional Studies* **25**, 525–541.

Legler, Harald, 1992, 'Innovationstätigkeit und Umfeld der Technologiepolitik in Niedersachsen – Kriterien für eine "strategische" Evaluierung', in Niedersächsisches Institut für Wirtschaftsforschung (ed.), *Erfolgskontrollen in der Technologiepolitik*, Hannover: NIW.

Little, William F., 1989, 'The Research Triangle Park of North Carolina – A U.S. Science City', in ACS Corporation Associates (eds.), *New Technologies in Pacific Basin Countries*, Honolulu: ACS, pp. 83–92.

Maillat, Denis and Bruno Lecoq, 1992, 'New Technologies and Transformation of Regional Structures in Europe. The Role of the Milieu', *Entrepreneurship & Regional Development* **4**, 1–20.

Malecki, Edward J., 1985, 'Public Sector Research and Development and Regional Economic Performance in the United States', in Alfred Thwaites and Ray Oakey (eds.), *The Regional Economic Impact of Technological Change*, London: Frances Pinter, pp. 115–131.

Malecki, Edward J., 1991, *Technology and Economic*

Development: The Dynamics of Local, Regional, and National Change, New York: Longman.
Markusen, Ann R., Peter Hall and Amy K. Glasmeier, 1986, *High Tech America: The What, How, Where, and Why of the Sunrise Industries*, Boston: Allen & Unwin.
Markusen, Ann R. et al., 1991, *The Rise of the Gunbelt. The Military Remapping of Industrial America*, New York/Oxford: Oxford University Press.
Marshall, M., 1987, *Long Waves of Regional Development*, New York: St. Martin's Press.
Matsubara, Hiroshi, 1992, 'The Japanese Semiconductor Industry and Regional Development: The Case of "Silicon Island" Kyushu', *The Economic Review of Seinan Gakuin University* **27**(1), 43–65.
National Academy of Sciences and National Academy of Engineering (NAS/NAE), 1969, *The Impact of Science and Technology on Regional Economic Development*, Washington: National Academy of Sciences.
Nelson, Richard R., 1984, *High-Technology Policies: A Five-Nation Comparison*, Washington/London: American Enterprise Institute.
Nijkamp, Peter (ed.), 1986, *Technological Change, Employment and Spatial Dynamics*. Lecture Notes in Economics and Mathematical Systems, Vol. 270, Berlin/Heidelberg/New York/Tokyo: Springer-Verlag.
OECD, 1992, *Science and Technology Policy. Review and Outlook 1991*, Paris: OECD.
OhUallacháin, Breandán, 1987, 'Regional and Technological Implications of the Recent Buildup in American Defense Spending', *Annals of the Association of American Geographers* 77(2), 208–223.
Peschel, Karin, 1989, *Spatial Effects of the Completion of the European Single Market*. Paper presented at 29th RSA European Congress, Cambridge.
Porter, Michael E., 1990, *The Competitive Advantage of Nations*, New York: Free Press.
Rees, John (ed.), 1986, *Technology, Regions, and Policy*, Totowa: Allen & Unwin.
Rees, John and John Stafford, 1986, 'Theories of Regional Growth and Industrial Location: Their Relevance for Understanding High-Technology Complexes', in John Rees (ed.), *Technology, Regions, and Policy*. Totowa: Allen & Unwin.
Roobeek, Annemieke J. M., 1990, *Beyond the Technology Race: An Analysis of Technology Policy in Seven Industrial Countries*, Amsterdam: Elsevier.
Rothwell, Roy, 1986, *Public Innovation Policies – Some international Trends and Comparisons*, Brighton: Science Policy Research Unit.
Saxenian, Annalee, 1985, 'Silicon Valley and Route 128: Regional Prototypes or Historic Exceptions?', *Urban Affairs Annual Reviews* **28**, 81–105.
Saxenian, Annalee, 1994, *Regional Advantage*, Cambridge, Mass.: Harvard University Press.
Scherer, Frederic M., 1992, *International High-Technology Competition*, Cambridge, Mass.: Harvard University Press.
Scott, Allen J., 1988, *New Industrial Spaces. Flexible Production Organization and Regional Development in North America and Western Europe*, London: Pion.
Scott, Allen J., 1992, 'The Role of Large Producers in Industrial Districts: A Case Study of High-Technology System Houses in Southern California', *Regional Studies* **26**, 265–275.
Scott, Allen and Michael Storper, 1990, *Regional Development Reconsidered*, Los Angeles: Lewis Center for Regional Policy Studies, University of California.
SRI International, 1984, *U.S. Government Programmes and their Influence on Silicon Valley*, Report Prepared for the Ministery of Industry and Research, Government of France, Menlo Park, CA: SRI.
Sternberg, Rolf, 1993, 'Wachstumsregionen der EG' (Growth Regions in the European Community), in Ludwig Schätzl (ed.), *Wirtschaftsgeographie der Europäischen Gemeinschaft*, Paderborn/München/Wien/Zürich: UTB, pp. 53–110.
Sternberg, Rolf, 1995, *Technologiepolitik und High-Tech Regionen – ein internationaler Vergleich* (Technology Policy and High-tech Regions – An International Comparison), Münster/Hamburg: Lit.
Stöhr, Walter B. and Richard Pöninghaus, 1992, 'Towards a Data-based Evaluation of the Japanese Technopolis Policy-The Effect of New Technological and Organizational Infrastructure on Urban and Regional Development', *Regional Studies* **26**(7), 605–618.
Storper, Michael and Richard Walker, 1989, *The Capitalist Imperative. Territory, Technology, and Industrial Growth*, New York/Oxford: Blackwell.
Sutherland, Ewan, 1993, *Silicon Glen; a Technological Brigadoon? An Analysis of the Electronics and IT Industries in Scotland*, IIR-Discussion Papers No. 48, Vienna: Interdisciplinary Institute of Urban and Regional Studies, University of Economics and Business Administration.
Thomas, Morgan D., 1975, 'Growth Pole Theory, Technological Change, and Regional Economic Growth', *Papers of the Regional Science Association* **34**, 3–25.
Thompson, Chris, 1988a, 'High-Technology Development and Recession: The Local Experience in the United States, 1980–1982', *Economic Development Quarterly* **2**(2), 153–167.
Thompson, Chris, 1988b, 'Some Problems with R&D/SE&T-based Definitions of High Technology Industry', *Area* **20**(3), 265–277.
Thompson, Chris, 1989, 'High-Technology Theories and Public Policy', *Environment and Planning C: Government and Policy* 7, 121–152.
Tichy, Gunther, 1991, 'The Product-Cycle Revisited: Some Extensions and Clarifications', *Zeitschrift für Wirtschafts- und Sozialwissenschaften* **111**, 27–54.
Tyson, Laura, 1992, *Who's Basing Whom? Trade Conflict in High-technology Industries*, Washington: Institute for International Economics.
Vernon, Raymond, 1979, 'The Product Cycle Hypotheses in a New International Environment', *Oxford Bulletin of Economics and Statistics* **80**, 190–207.
Wells, Peter, 1987, 'The Military Scientific Infrastructure and Regional Development', *Environment and Planning A* **19**, 1631–1658.