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Research and Development Effects on Economic Growth: Implications for the Portland SMSA

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INTRODUCTION

Promoting a high-technology economic base has been widely adopted as a regional development "policy for the 80's." To this point, however, it appears that little consideration has been paid to questions regarding the feasibility of this policy as it relates to structural and locational characteristics of the regional economy. This paper will discuss those attributes of the regional economy that typically contribute to the expansion of high-technology activities, with particular attention paid to expansion potential in the Portland SMSA. High-technology activities are defined according to product cycle theory, and the attributes of the regional economy are examined with respect to each stage of the product cycle. The contribution of research and development to the product cycle will receive special attention. The role of the area's higher educational system in performing research is tied to high-technology development potential. It is contended that development potential is maximized when the regional economy exhibits a comparative advantage in one or more stages of the product cycle. Actions which are needed to direct the regional economy toward this end will be outlined.

BACKGROUND

The emphasis that regional and local jurisdictions have placed on encouraging growth in high-technology[1] activities is in large part attributable to their recent growth performance. As a report of Congress' Joint Economic Committee notes (JEC. 1982; p. 5), U.S.

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[1]Defining "high-tech" has become an exercise in itself. Some argue that virtually all sectors of the economy contain some degree of high-tech activity. Others base their definition on the relative intensity of R&D activity (e.g., rates of innovation or research expenditures; the relative employment of scientific and engineering personnel...). This paper is not concerned with what industries should be logically included in this category. When necessary, we adopt the classification used by the Joint Economic Committee (1982) which includes the following 2-digit SIC categories: 28, 35, 36, 37 and 38.

employment in high-technology industries has grown much more rapidly over the past 25 years than employment in other manufacturing sectors. The JEC growth figures are reprinted in the table below.

Table I
U.S. Employment in Manufacturing: 1955-1979
(in thousands)

	1955	1979	% change
High Tech	5,590.9	8,422.6	+50.6
Other Mfg.	11,191.1	12,550.4	+12.1
Total Mfg.	16,882.0	20,973.0	+24.2

Moreover, the current conventional wisdom is that the relative discrepancy in growth rates between high tech and other manufacturing employment will continue in the future.

At this point there seems to be less uncertainty about the general prospects for growth in high-tech activity compared to the uncertainty associated with where this growth will occur. Unfortunately, conventional location theory (e.g., Isard, 1960) offers little in the way of shedding light on the latter question. This is because the optimal locations of high-technology firms are constrained neither by raw material nor market considerations. Thus, they have been characterized as "footloose"--free to chose locations based on factors (often nonquantifiable) other than those applied in traditional analyses.

To date, there has been little effort devoted to systematic analysis of the factors influencing the locational choices of high-tech firms. Generally, we know that these firms are less sensitive to traditional spatial considerations and more sensitive to factors related to variations in economic, social, political and educational environments in choosing plant locations. This has several implications. The first is that the industrial recruitment "game" becomes more competitive in that states and metropolitan areas may conclude that because the industries are footloose, they should be able to attract some form of high-tech activity. Thus, while national high-technology growth prospects appear promising, there are also an abundance of independent regional development plans aimed at reaping the locational rewards. A little logic suggests that there may be more plans than plants, and that some jurisdictions may come up empty handed despite their efforts.

A second implication is less certain, but probably more significant. Because location decisions of high-tech firms depend more on "composite" judgments whose elements are both more diverse and indeterminate in comparison with traditional location theory, greater uncertainty surrounds the determination of the course that should be taken by any local jurisdiction to enhance its locational "appeal". Even more troubling is the possibility that no practical level of effort will substantially improve the locational prospects of some jurisdictions. It is of little consolation to public officials to realize that a large investment targeted to attracting high-technology firms has made their jurisdiction "a little less unattractive" to these industries.

One attempt to consolidate the factors bearing on the plant location problem entails the construction of an index of "business climate" (e.g., Alexander Grant and Co.; 1982). The index is comprised of a weighted combination of factors hypothesized to be key determinants of business location expansion decisions. Interpretation of these indices is fairly straightforward: areas having a high composite rating are more likely to attract firms and experience growth than areas with a low rating. Furthermore, it is suggested that because some of the factors comprising the composite fall within the domain of the public sector, the composite is sensitive to public policies.

Two related points should be noted regarding the use of these indices:

- No rigorous validation of the relationship between regional economic development and the business climate scores has yet been reported.

- There has been no confirmation of the marginal effects (weights) of individual elements comprising the composite indices on economic development.

Initial findings of research in progress by the author suggest that the relationship between business climate and economic development is not as straightforward as these indices imply. We would only suggest at this point that the manipulation of those factors falling within the public domain may not noticeably enhance a state's growth prospects, and may generate effects best described at this point as perverse.[2]

Others have confronted the problem of determining an appropriate strategy for enhancing local high-tech development potential and have come away similarly perplexed. Gurwitz (1982), for example, concludes that:

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[2]With the assistance of Lawrence Conrad and Michael Hayakawa, the author is currently testing the statistical relationship between measures of comparative state-level economic performance and measures defined as contributors to "business climate," for the 1975-1979 period. While it is still too early to draw specific conclusions, the initial results suggest that:

- A number of factors cited as elements contributing to business climate were not significantly related to state economic performance during the test period.

- The effects of some elements varied across the types of industries considered.

- Several elements demonstrated a statistically significant effect in the opposite direction hypothesized in the business climate index.

> "because there are a large number of factors that drive firms' choice of locations, because these factors are poorly understood and because very few of the important determinants of locations are controllable, there is precious little any government, local foundation or chamber of commerce can do to stimulate the growth of specific industries in a locality with certainty."

Considering the spate of economic development plans tied to the attraction of high-tech firms, this conclusion has very unsettling implications. There is, on the other hand, evidence suggesting that the high-tech location problem is not as confounding as some have claimed. Recent contributions to locational analysis in the geography, regional science and economics literatures have provided a more logical basis for assessing the feasibility and scope of a high-tech development plan for any given region.

These contributions redefine the context of locational analysis for the case where consideration of continuous space is not a central feature of the optimal solution. In this context the high-tech locational problem would appear at first glance to revert to the neoclassical cost min./profit max. production problem applied comparatively across regions. As we will see later, however, this interpretation fails to capture the strategic locational behavior of firms with respect to time-dependent phenomena associated with the product cycle. These factors exert an influence on industry behavior that results in locational "indeterminancies" based on time in a manner analogous to Moses' (1956) indeterminancy based on scale.

THE CONNECTION BETWEEN R&D AND REGIONAL DEVELOPMENT

In this section we review the relationship found between R&D and economic growth in selected studies. We then draw inferences from these results regarding their implications for regional economic development. Finally, we address the question of underinvestment in R&D activity, identify the conditions that lead to underinvestment and suggest possible public sector contributions to resolving this problem.

The focus on economic returns to R&D activity is a logical one in considering the growing contribution of high-tech industries to the national economy. In Table I we saw the increasing share of national employment attributable to these industries. Here we attribute this growth to the effects of innovations resulting from R&D investments.

Economic growth induced by innovation comes about in two ways. The first posits that successful innovations must result in acceptable profits for the innovator. That is, the development of a new product or process and its adoption in the marketplace comes about because the innovator is able to provide a product or service at a price that allows a sufficient return on development costs. This is defined as the "internal" return to the innovator. Secondly, the successful innovation must offer potential savings to its users. These savings, measured collectively over all users, are defined as "external" returns. Taken together the internal and external returns to the development of innovations comprise what is termed the "social" return.[3]

These points are illustrated graphically in Figure I. The adoption of an innovation has the effect of shifting the supply curve of its users downward ($S_1 \rightarrow S_2$). The magnitude of this shift depends both on the potential savings entailed in adoption and the pricing policy of the innovator. In Figure I a price has been set by the innovator that results in a unit cost savings

[3]In defining the social returns to an innovation one must further account for the opportunity cost of the private returns from any product or process the innovation might replace. To the extent that such an opportunity cost exists, social returns will be lower than they otherwise would be.

Figure 1

Internal and External Returns from
the Adoption of an Innovation

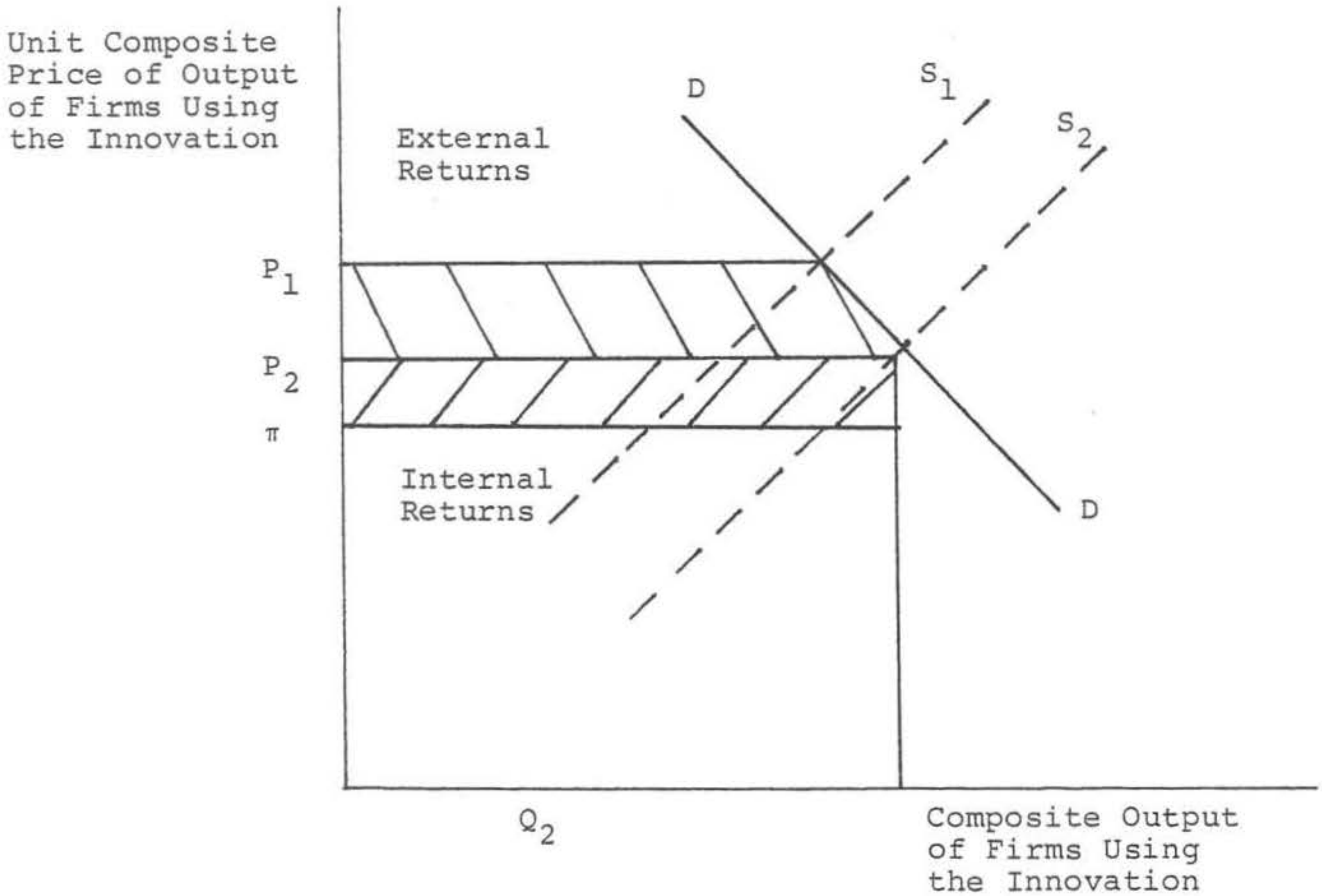

TABLE II

Mansfield's Estimates of Social and Internal Rates of Return From Investment in 17 Innovations

Innovation Sources	Rate of Return Social	Rate of Return Internal
Primary Metals	17	18
Machine Tools	83	35
Component for Control System	29	7
Construction Material	96	9
Drilling Material	54	16
Drafting	92	47
Paper	82	42
Thread	307	27
Door Control	27	37
Electron Device	negative	negative
Chemical Product	71	9
Chemical Process	32	25
Chemical Process	13	4
Major Chemical Process	56	31
Household Cleaning Device	209	241
Stain Remover	116	4
Dishwashing Liquid	45	46
Median	56	25

to the users equal to $P_1 - P_2$. This price further allows a unit profit to the innovator equal to π, which is also measured with respect to the output of the users. The upper shaded area in Figure I measures the total external returns attributable to the users of the innovation while the lower shaded area measures the total internal returns to the innovator. The two areas combined measure the total social returns.

Mansfield (1977) estimated the internal and social rates of return on R&D investments for a selected group of industrial innovations. His results are presented in Table II. Several things stand out in interpreting these estimates. First, the internal returns to R&D-induced innovation are substantial, with a median present rate of return of 25%. If we use a rate of 15% as the benchmark defining an "attractive" investment,[4] roughly 65% of the innovation-specific investments in Mansfield's study generated desirable returns to the innovator. Furthermore, we note that the median social rate of return was more than double the internal rate, indicating a substantial savings also accruing to users of the innovations. Finally, in scanning the range of innovations studied, we see that a number are not associated with what is commonly thought of as high-technology products. A perusal of the results further suggests no apparent difference in rates of return in high-tech versus non-high-tech innovations. In fact, what typically distinguishes high-technology research from that of other manufacturing is its greater relative intensity. As Leonard (1971) found, the intensity[5] with which firms engage in R&D shows a strong relationship to subsequent growth in sales.

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[4]This benchmark applies to the study period (1960-1972). The present investment climate suggests that a higher rate would apply.

[5]Research intensity has been variously defined as:

- R&D as a percent of net sales;
- Scientists and engineers per 1,000 employees;
- Median education levels of employees.

And because high-tech firms are often defined in terms of their higher levels of research intensity, we would expect, ceteras paribus, their overall growth rates to be greater as a result. However, as Mansfield's results clearly reveal, this does not rule out significant potential gains from "non" high-tech R&D, especially at the margin. What inferences can be drawn from these conclusions with respect to the development of a regional economy? Obviously, they suggest that to the extent a region is successful in achieving a relative concentration of research-intensive activity, prospects for greater than average economic growth are likely to be enhanced. Thus, the logic underlying the wide-spread efforts of states and locales to attract research-intensive high-tech firms is clearly justified.

We state again, however, that it appears that there may be more jurisdictions than opportunities for high-tech business attraction. In this light, the findings suggest that jurisdictions adopt a broader perspective in setting economic development objectives. While these objectives may do well to emphasize the importance of R&D and innovation, this does not imply that focus of development planning be limited to high-technology.

In addition, a shift in orientation from the national to the regional setting is not achieved without encountering several complexities. Referring to Figure I, we again note the downward shift in the supply curve induced by the adoption of an innovation. This shift represents a cost-saving technical change in the collective production function of the innovation-using firms. More specifically, the shift reflects a directed increase in factor productivity of the user firms. At the national level this phenomenon (innovation-induced technical change) provides a major rationale for supply curve shifts and subsequent economic expansion. This is not necessarily so at the regional level. Because the regional economy is quite "open" relative to the national economy, cost-reducing structural change can come about apart from R&D-induced innovations. Combined with innovation-induced changes in technology these structural changes can enhance a region's comparative advantage relative to other regions, producing growth from both increased demand and increased market share. A recent study (Strathman and McPherson; 1982) of the Portland SMSA inter-industry structure concluded that substantial gains were possible in the latter context.

Taken together, the regional growth opportunities associated with the promotion of research intensive activities and structural change offer a broad set of options to development planners. By focusing solely on R&D-intensive activities (or, more appropriately, that subset we call "high-tech")and ignoring what Gerwitz (1982) terms "regional housekeeping chores", some attractive regional development opportunities are likely to be missed.

The challenge currently facing regional development planners lies in determining a proper balance between attentions devoted to housekeeping and high-tech. Suggesting such a balance is beyond the intent of this paper. However, because some information is already available on regional housekeeping matters, it would seem useful to explore what should be entailed in assessing the regional growth potential of research-intensive activities. Because the determinants of this potential are primarily region-specific, we will couch the assessment focusing on the Portland SMSA.

The progression from R&D to innovation to technical change and finally economic growth can be viewed as an evolutionary process. For a single industry or product this process has been defined in terms of stages comprising initial product development, commercialization and final obsolescence. Vernon (1966) defines this progression as the "product cycle". Economic geographers (e.g., Malecki, 1981; Norton and Rees, 1979; Rees, 1979; Thomas, 1975) have further explored the locational behavior of firms from this perspective. More generally, the theory has been advanced as a framework for explaining the process of regional economic growth and decline. In this context, the strength of the theory lies in its ability to decompose the regional growth process into its component parts. In doing so the theory, coupled with analysis of pertinent empirical evidence, can uncover a region's relative strengths and weaknesses with respect to each phase of the product cycle. It is sometimes the case that a region's comparative locational advantage will change with each phase of the product cycle. Thus, it may be important for development planners to assess the attributes of the regional economy in light of product cycle theory, and target for development those activities corresponding to product phases where the region holds a comparative advantage. With reference to potential expansion of high-tech activities in the Portland area this suggests that we should devote our attentions more appropriately to that phase of the "high-tech product cycle" where Portland's comparative advantage is greatest.

The initial phase of the product cycle is characterized by an emphasis on research and development activity. As was demonstrated earlier, these efforts tend to produce favorable returns, from the standpoint of both internal financial gains and external growth. Locationally, this phase has been shown to be concentrated in select urban centers in the U.S. (Malecki, 1980a). Because the first product phase depends heavily on scientific input, locations offering access to top flight centers of higher education hold a distinct comparative advantage. Agglomerative forces[6] further encourage the clustering of firms performing these activities. The research activities may have a similar purpose across firms, but more frequently they do not.

The conclusion of the first phase is marked subsequent to successful introduction of a new innovation in the marketplace. Unit production costs are usually still quite high at this point,

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[6]These forces may encompass knowledge spillover effects, and employment transfers between individual firms, and between firms and higher educational institutions. See Malecki (1980b).

suggesting (with reference to Figure I) that while limited adoption of the innovation has taken place, the supply curve of the user firms has yet to fully shift downward.

The second phase of the product cycle is characterized by rapid expansion of new product sales and corresponding reductions in the cost of manufacturing the product. This stage is often referred to as the "commercialization phase". The degree of cost reduction is typically attributed to the combined effects of scale economies, manufacturing process development and competition between producing firms. From a locational standpoint, once the product becomes standardized, it is no longer necessary for the innovator to retain close access to the R&D centers. Thus, this phase may also be characterized by spatial deconcentration in the manufacturing of the product. Regions suffering a comparative disadvantage with respect to the innovation phase might gain in the commercialization phase by virtue of offering cost-minimizing manufacturing locations.

Data covering the 1977-1980 period indicates that Portland was a beneficiary of the deconcentration trend in high-technology manufacturing (Strathman and McPherson, 1982). Using the Joint Economic Committee's definition of high-tech industries, the metropolitan area gained in its share of national high-tech employment. The net gain in metropolitan employment relative to the nation amounted to about 1,200 jobs. A breakdown is presented in Table III.

Results of the Joint Economic Committee's survey of the expansion plans of the nation's high-tech firms conclude that the trend observed in Table III may be reversed in the 1982-1986 period. The survey concludes that net employment gains will occur in the Midwest, Southeast, Southwest and Mountain regions, while net losses are expected in the New England, Mideast and Far West regions. The foreseen decline in the Far West, however, may be primarily concentrated in the State of California.

TABLE III

Portland SMSA Net High-Tech Employment Gain, 1977-1980

SIC category		Employment Growth Relative to the Nation*
28		+100
35		+1,500
36		+4,000
37		+600
38		-5,000
	Net Overall	+1,200

*rounded to the nearest hundred

Unfortunately, state-level results were not reported, and so little can be said on the subject of intraregional shifts.[7]

Returning to the product cycle, the final product phase occurs when the domestic market for the product becomes saturated. To achieve greater than average growth rates in this phase the product must gain a favorable position in international markets.

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[7]The locational concentration of the respondents to the JEC survey also raises several questions. Of the 691 responding firms, 322 were from California, 190 were from Massachusetts and 179 were from other states. According to the report "(n)o attempt was made to stratify the sample by state or region" (p. 19). If the locational distribution of the responding firms differs from the industry as a whole, this could affect the results obtained. The JEC survey does not report the breakdown of responses by state and so we are unable to address this issue. In some cases (e.g., see Table III.9 in the report) the responses attributed to the Far West region suggest a heavy California influence.

As an aside, we were quite perplexed by the absence of Oregon in the section of the report assessing state-level historical performance in the high-tech industries. The twenty-four states included in this section were chosen "...because of their general importance to the high-technology industries..." (p. 10) among other things. As measures of employment concentration (e.g., location quotients) show, Oregon's "importance" to high-technology industries is substantial.

Successes observed in this phase are almost entirely attributable to efforts to minimize production costs. Attention to scale economies and process efficiency in manufacturing and promoting more diverse applications of the product line become the primary concerns of the producer. Growth of the firm or industry in the final phase of the product cycle can also occur as the result of mergers and acquisition of either competitors (increasing concentration in the industry), or forward and backward-linked firms (increasing vertical integration).

From a locational standpoint the industry may become more concentrated spatially in the final phase of the product cycle. Spatial concentration will tend to occur at those locations where the combined costs of production and distribution to final markets (total locational costs) are minimized. The extent of spatial concentration and the determination of its locational orientation are subject to numerous influences. The interplay of three factors are key to the analysis. First, significant economies of scale permit a given level of demand to be satisfied by fewer plants, each producing large quantities. Secondly, gains from economies of scale are offset by the marginally increasing cost of transporting the final product to its markets. To the extent that marginally increasing distribution costs are more than offset by marginal savings from scale economies, spatial concentration will increase (Scherer, 1975; Strathman, 1981). Because high-technology products typically exhibit high value relative to their weight, the effects of distribution costs on limiting the optimal level of output per plant will be lessened. Thirdly, the competitiveness of the industry in international markets will be largely influenced by the combined effects of the two previously mentioned factors, contrained by the trade policies of foreign governments. Taken together, these factors will largely determine the spatial extent over which an industry is capable of gaining competitive market control. There is little empirical evidence assessing the spatial extent of market control for industries falling under the scope of this paper. Weiss (1972) derived estimates that are quite detailed by product, but limited his analysis for domestic markets. A majority of the high-tech products in the Weiss study were judged to be competing for a single national market. We further suspect that apart from consideration of trade barriers--these products would be viable competitors at the international scale as well.[8]

The product cycle is concluded when a new innovation is introduced as an eventual substitute for a mature product. Industries (and regions) tied to the fortunes of the mature product may face the prospect of decline as the new innovation gains favor in the marketplace. Regional decline may be especially exacerbated if the new innovation evolves according to a differing set of locational characteristics (Norton and Rees, 1978). Industries (and regions) can avoid these contracting effects through multi-product diversification efforts as well as diversifying across the phases of the product cycle. The successful industry (and region) is capable of reallocating its resources in line with new product requirements. In a word the industry (or region) is more flexible in adapting to the phases of the product cycle.

The Portland area economy appears to be well-positioned with respect to benefiting from the high-technology produce cycle. As we have shown, Portland's performance in the commercialization phase of the cycle has exceeded the national norm. Furthermore, the city's port facilities provide an excellent linkage to international markets, which will become more important in the final product phase. However, it has been noted (SRI International, 1982) that the metropolitan area is deficient in the level of

[8]The JEC study does report (p. 29) an anticipated relative gain in overseas plant additions in the 1981-1986 period, indicating spatial diffusion rather than concentration. However, this may only reflect the effects of trade restrictions in inducing technology transfers to foreign markets.

support provided to graduate engineering programs and the performance of research and development in higher education. This shortcoming may not seriously impair the city's performance in the current cycle of high-technology products. However, continued inattention to the higher education "shortfall" reduces the area's potential gains from the development of future generations of innovations--gains from product cycles yet to be initiated.

Portland's economic performance in light of product cycle theory, exhibits apparent comparative strength in two of three product phases. It is also encouraging that in the phase where weaknesses are evident--the support of research and development--remedies are feasible. It would be, for example, far easier to increase the commitment to graduate education and research in Portland than to attempt to change the area's locational attributes.[9] Moreover, placing an increased emphasis on research and development activities will likely generate additional economic benefits in terms of "locational spillovers" to the other product phases.[10] Thus, greater research intensity may generate even greater future commercialization activity in the area than would otherwise be the case.

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[9]Obviously, there are many locational factors that are not subject to modification (e.g., access to markets and raw materials, climate, transportation costs). And, with respect to those factors falling in the public domain, there is hardly a consensus as to what changes would favorably affect the combined economic and social well-being of the region.

[10]That is, as the product cycle evolves from the innovation to the commercialization phase, business may be more prone to remain in the region so long as the region's locational attributes are <u>sufficiently</u> attractive (as opposed to <u>maximally</u> attractive) in comparison with alternative locations. For example, suppose that a firm which has benefited from its location supporting research intensity finds that one of its innovations has reached the threshold of commercialization. The firm may take an assessment of its current location and conclude that it is suboptimal for the purpose of cost-minimizing production. Given this, it sets out to find that production location possessing the optimal (continued)

Shortfalls in the regional higher educational system have been identified and recommendations for action have been proposed by The Western Interstate Commission for Higher Education (WICHE, 1983). Though the commission was concerned with issues pertaining to higher education and high-technology in all the Northwest states, its conclusions appear to be particularly relevant for Portland. With respect to higher education's contribution to high-technology research and development, the Commission proposed that a substantial commitment be made to:

- Attract high-technology R&D scientists into academia, give them competitive compensation and provide them with a working environment conducive to making significant contributions to scientific knowledge.

- Upgrade the research and development facilities in the higher educational system.

- (In consultation with government and industry) make necessary curriculum changes to better prepare students for the field.

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[10] (continued) cost-minimizing combination of attributes with respect to successful product commercialization. The end result is that the firm's production activities become spatially distinct from its research and development activities. This separation is accompanied by some loss of organizational control and managerial and administrative duplication, but it is assumed that the economies offered by each of the locations more than offset these effects. On the other hand, the firm may discover that its R&D location, while not "optimal" in comparison with the cost minimizing production location, offers a set of attributes that are sufficiently attractive to avoid the added "overhead" costs involved with the spatial separation of activities. Given a commitment to a significant R&D focus, we feel that the latter type of solution would be applicable to the Portland setting. This feeling is in part reinforced by the responses obtained in a Portland Development Commission survey (PDC, 1982) of the expansion plans of area manufacturing firms. Hekman's (1980) survey of branch plant location in the computer industry lends additional support.

- Encourage greater participation of high-technology industries in the higher educational system. The scope of participation would include, among other things:

  - shared appointments/"executive loans";
  - corporate contributions to enrich faculty salaries and promote research;
  - cooperative research projects;
  - provision of state of the art research equipment and facilities;
  - assistance in manpower and curriculum planning.

In substance, the Commission's recommendations address current shortcomings in the higher educational system pertaining to supplying basic scientific prerequisites to future growth in the region's high-technology industries. The Portland economy would benefit greatly were these recommendations to be carried out. By closing the gap in the product cycle, the implementation of a high-technology research and development base in Portland would not only provide attractive direct economic returns, it would also reinforce the comparative advantages found here in the other product phases.

In addition to satisfying an apparent demand for personnel and facilities, a commitment to enhance higher education's high-technology R&D capacity must also consider whether underinvestment in high-technology R&D generally exists and, if it does, what should be done to raise the investment to a socially optimal level.

Underinvestment in R&D can be viewed as a failure of the market to properly allocate private resources. The extent of R&D

underinvestment is influenced by the ability of the investing party to capture the internal benefits of resulting innovations. If the spillover of benefits from an innovation becomes sufficiently large, private returns to the innovator may become too small to warrant investment. Referring again to Figure I, underinvestment occurs when the size of the lower shaded area falls below what would be considered an acceptable internal return to the innovator. If this occurs, the opportunity cost to society can be taken to be the size of the upper shaded area plus the value of the internal returns foregone. According to Mansfield (1972, p. 480), underinvestment in R&D can be significant. He concludes that

> because the results of research are often of little direct value to the sponsoring firm but of great value to other firms, there is good reason to believe that, left to its own devices, the market would allocate too few resources to R&D[11]--and the shortfall would be particularly great at the more basic end of the R&D spectrum.

While no estimates have been made of the magnitude of underinvestment in R&D, there is general agreement that the current level of R&D spending (by both the public and private sectors) is too low.

Apart from the question of the amount of underinvestment is the issue of how the shortfall in R&D activity is distributed regionally. In fact, the relative amount of underinvestment may be a more appropriate measure when it comes to assessing comparative regional advantage in the innovation phase of the product cycle. While national R&D policy targets funds for activities where underinvestment is judged to be greatest, the regional allocation

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[11] This condition is analogous to the free rider problem in the provision of public goods.

of federal R&D funds has tended to exacerbate a priori imbalances (Malecki, 1982).

Given the inherent lack of consideration of the distributional consequences of federal R&D programs, states have become more active in fostering a strong technological base (JEC, 1982). Strengthening the research capacity of the university system is a central feature of many of the state development efforts. While few would debate the logic of investments in the higher educational system--the returns are well documented--the question of "who shall pay" for this commitment remains. Conceptually, the answer to this question is straightforward. The "beneficiaries" of R&D are identified and charged an amount corresponding to the value of the marginal benefits they gain. In practice, however, both the beneficiaries and associated values are diverse and not easily measured. Due to the presence of considerable uncertainty, then, it is likely that the funding question will only be resolved through a process of collective decision-making, involving all potential beneficiaries. As one would expect, the outcomes of such a decision-making approach are likely to be quite varied (e.g., JEC, 1982; University of Washington, 1982).

CONCLUSION

The effects of research and development in innovation-intensive areas have been outlined in the context of regional economic development. Both the internal and external returns to R&D investment were shown to be significant. In addition, we discussed how the development potential of the Portland metropolitan economy would be enhanced by increasing the commitment to the performance of R&D. A commitment to R&D performance in the area's higher educational institutions, coupled with changes in curriculum, facilities, faculty workloads and compensation would lessen the product cycle gap that currently exists in the Portland economy. These actions would provide significant locational economies to high-technology firms, improving

Portland's comparative locational advantage relative to other areas in a critical phase of the product cycle.

Less can be said regarding the composition of the commitment that will be required to bring about the necessary changes in research performance. A number of considerations were identified and need to be resolved within the framework overseeing the development of high-technology research in Portland. Because the effects of these considerations take the form of externalities, a close examination of the range of benefits resulting from a commitment to high-technology research should be undertaken. The externality given most attention here deals with the spillover effects of R&D on Portland's economic growth, viewed in terms of product cycle theory. A second externality concerns a market failure resulting from an underinvestment in R&D and educational programs.

A 1983-84 commitment to Portland State University of approximately $2.6 million in state and private resources has been targeted to alleviate the shortcomings found in high-technology related research and education. This effort represents a significant step, addressing the problem of underinvestment in areas of importance to both public and private interests. The joint commitment of public and private funds recognizes that the benefits derived from a greater emphasis on high-technology research and education will be twofold:

- From an industry perspective, the PSU program will offer area firms greater access to the scientific "inputs" that produce technological innovations.

- From a public perspective, the program will enhance prospects for economic development by reducing the innovation gap that currently exists in the Portland area. As such the public stands to gain as users of future innovations, not to mention the economic spillover effects these innovations will have on other phases of the product cycle.

The effects of committing resources to close the innovation gap may be difficult to measure.[12] Additional effort should be devoted to determining the full range of interests affected by the externalities discussed here, and steps should be taken to see that these interests are represented both in oversight functions and in the support provided to related programs.

[12]As we noted earlier, the areas where underinvestment is most prevalent--basic research, research with significant spillover effects, and research associated with substantial financial risk--are not undertaken in the private sector because of an inability to internalize the benefits. As a result, we can expect, a priori, that any public commitment to these areas will produce a diverse range of effects no less easily determined. The difficulties associated with this problem are evident in studies (e.g., Griliches (1980); Leonard (1971)) concluding that federal investment in basic R&D results in significantly lower rates of return than corporate R&D investment. To some extent this difference can be attributed to the large proportion of federal R&D funds devoted to defense research (the results of which may not easily transfer to commercial use), the longer time lags associated with the evolution of basic research to innovation to commercialization, and the difficulties involved in determining the full range of benefits resulting from basic research.

REFERENCES

Alexander Grant and Co., General Manufacturing Business Climates, 1981.

Griliches, Z., "Returns to Research and Development Expenditures in the Private Sector," in J.W. Kendrick and B.N. Vaccara (eds.) New Development in Productivity Measurement and Analysis, (NBER Studies in Income and Wealth, Vol. 44). Chicago, University of Chicago Press, 1980.

Gurwitz, A.S., "The New Faith in High Tech" The Wall Street Journal, Oct. 27, 1982.

Hekman, J.S., "The Future of High Technology Industry in New England: A Case Study of Computers," New England Economic Review, Jan./Feb. 1980.

Isard, W., Methods of Regional Analysis, Cambridge, Mass., MIT Press, 1960.

Joint Economic Committee, Congress of the United States, Location of High Technology Firms and Regional Economic Development, U.S. Government Printing Office, 1982.

Leonard, W., "Research and Development in Economic Growth," Journal of Political Economy, Vol. 79, 1971.

Malecki, E.J., (1980a), Regional Economic Effects of Federal R&D Spending: A Study of U.S. Metropolitan Areas, Department of Geography, University of Oklahoma.

____________, (1980b) "Corporate Organization of R&D and the Location of Technological Activities," Regional Studies, Vol. 14, pp. 219-234.

____________, "Public and Private Sector Interrelationships, Technological Change, and Regional Development," Papers, Regional Science Association, Vol. 47 (1981).

____________, "Federal R&D Spending in the United States of America: Some Impacts on Metropolitan Economies," Regional Studies, Vol. 16, pp. 19-35 (1982).

Mansfield, E., "Contributions of R&D to Economic Growth in the United States," Science, Vol. 175, No. 4021 (Feb., 1972).

____________, et al., "Social and Private Rates of Return From Industrial Innovations," Quarterly Journal of Economics, Vol, XCI, No. 2 (May, 1977).

Moses, L.N. "Location and The Theory of Production," Quarterly Journal of Economics, Vol. 72 (1958).

Norton, R.D. and J. Rees, "The Product Cycle and the Spatial Decentralization of American Manufacturing," Regional Studies, Vol. 13, pp. 141-151 (1979).

Portland Development Commission, Survey of Manufacturers, 1982.

Rees, J., "Technological Change and Regional Shifts in American Manufacturing," The Professional Geographer, Vol. 31, No. 1 (Feb., 1979).

Scherer, F.M. et al., The Economics of Multi-Plant Operations: An International Comparisons Study, Cambridge, Mass., Harvard University Press, 1975.

SRI International, Strengths and Weaknesses of The Portland Area As An Industrial Location, prepared for the Portland Chamber of Commerce, July, 1982.

Strathman, J., Estimating the Effects of Increased Energy Prices on Production and Location in the U.S. Cement Industry, Ph.D. dissertation, The University of Iowa, 1981.

____________, and S. McPherson, Estimating Growth Potential in Selected Manufacturing Sectors of The Portland SMSA, Report prepared for the Portland Development Commission and the Port of Portland, November, 1982.

Thomas, M.D., "Growth Pole Theory, Technological Change, and Regional Economic Growth," Regional Science Association, (Papers), Vol. 34, pp. 3-25, 1975.

University of Washington, A Proposal for the Washington High Technology Center: A Government Industry Initiative, September, 1982.

Vernon, R., "International Investment and International Trade in the Product Cycle," Quarterly Journal of Economics, Vol. 80, pp. 190-207 (1966).

Weiss, L.W., "The Geographic Size of Markets in Manufacturing," The Review of Economics and Statistics, Vol. 54 (1972).

Western Interstate Commission For Higher Education, High Technology Manpower Problems In The West: Strategies For Action, Jan., 1983.