# TECHNOLOGY AND REGIONAL DEVELOPMENT IN THE AMERICAN CONTEXT

John Rees
Howard Stafford
Ronald Briggs
Raymond Oakey

August, 1983
CP-83-39



INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
A-2361 Laxenburg, Austria

# PREFACE

Many large cities in the developed countries have recently experienced a slow-down of growth, and in some cases, absolute contraction of their population size. These trends pertain in particular to old industrial agglomerations which often fail to adapt to the changing demands and locational requirements of modern production facilities and to differentiate their employment structure.

Interrelations between industrial restructuring and urban regional change were among topics studied in the former Human Settlements and Services Area at IIASA. They are also of current research interest to the Regional and Urban Development Group. The paper by J. Rees, H. Stafford, R. Briggs and R. Oakey touches on several aspects of those interdependencies, especially the question of how do high-technology complexes develop over space.

Dr. Rees, who stayed at IIASA during July, 1982, is now Associate Professor of Geography, Maxwell School of Citizenship and Public Affairs, Syracuse University. Dr. Stafford is Professor of Geography, University of Cincinnati. Dr. Briggs is Associate Professor of Geography, University of Texas at Dallas. Dr. Oakey is Research Associate, University of Newcastle, United Kingdom.

Part II of the paper has been done within a framework of an international collaboration project involving similar studies in the U.K. and F.R.G. and coordinated by Professor John Goddard of Newcastle, U.K.

P. Korcelli
Research Scholar

B. Johansson
Acting Leader, RUD

August, 1983

CONTENTS

PART I:

# A REVIEW OF REGIONAL GROWTH AND INDUSTRIAL LOCATION THEORY: Towards Understanding the Development of High-Technology Complexes in the United States

John Rees and Howard Stafford

Summary

In order to understand the development of high-technology complexes around the United States, useful insights can be gained from reviewing two major bodies of theory: that dealing with regional economic growth in a macro context, and industrial location theory in a micro context. The relative importance of location factors that impact high-technology industries can be assessed from these theories, and suggestions made for both state and federal policy to complement rather than contradict each other in the common pursuit of nurturing innovation, enhancing productivity and increasing economic growth at the national level.

Theories that explain regional economic growth deal with technological change in a variety of ways.

- Export base theory asserts that economic performance is a function of a region's export base, either natural or human, and suggests that the more successful export industries are technology-intensive, therefore resulting in higher levels of regional productivity. High technology industries can have higher inter- and intra-regional multiplier effects that hasten the process of regional economic growth.
- Factor price equalization theories explain how capital and labor can flow inter-regionally to seek their highest return, and studies of economic decentralization from North to South in the last twenty years have related per capita income convergence in the

United States to the growth of key high-technology sectors in particular regions.

- Growth Pole theory explicitly recognizes the importance of propulsive, high-technology sectors in the urban growth process, and how such centers can perform as incubators or seedbeds for the birth of new industry.
- The product and regional life cycle theories of regional development recognize that industries and products have different locational requirements at various stages of their development. Therefore, while new product development tends to take place in R&D-intensive locations like Boston, New York or the San Francisco area; mass production techniques allow production to take place in more peripheral areas like the Carolinas, Georgia and TExas where labor costs have traditionally been cheaper.
- Diffusion theory is more concerned with the spread of innovation than its generation. Yet the speed with which productivity enhancing innovations spread between regions of this country can play a critical role in accelerating the economic growth process.

Though the above are partial theories that explain different aspects of the regional development process, there does not appear to be any need for a new theory to explain the development of high technology complexes in the United States. Growth pole and product cycle theory together are particularly appropriate explanatory frameworks in this regard. Indeed, when these are integrated into a regional life cycle framework, much insight can be gained about contemporary growth and change in the various regions of the country. Growth centers or "Sunspots" in the South and West can be seen as new economic structures in new regions that have by-passed the obsolescent plants of the old industrial heartland. On the other hand, the economic transformation of New England coupled with increasing inflation in the growth areas of the South and West may result in a new regional equilibrium in the United States where both the momentum of the new growth centers and the indigeneous technological potential of the older heartland may result in both areas growing in the future, even if at relatively slow rates.

Industrial location theory tells us that the executives of high-technology companies undertake their locational search in much the same way as executives of other companies. Yet the factors that attract them into a community or at least the priority given to various factors can be different from other companies.

- Appropriate labor is by far the most important single variable that influences the locational search of a high-technology company executive.
- Several other key location factors also relate to this human factor. Important are the qualities of life in an area: the existence of good schools and universities for the attraction, training and retention and

skilled workers and managers; and the recreational amenities of an area.

High-technology industries are not as closely tied to the location of materials or markets as are other industries. On the other hand, they are not footloose either, given that the labor-orientation itself can be locationally constraining.

There is no reason to believe that high-technology companies will be overly influenced by fiscal incentives at the State or local level, any more than other companies would. Indeed, the best inducement strategy for a state or city to lure high-tech companies is to support a human capital strategy that emphasizes the training and retraining of labor and quality education in general.

Because of the increasing involvement of states and cities in intense competition for high-technology jobs, it has become even more important recently for communities to be aware of the location factors perceived to be important by corporate executives.

Hence, there exists a need for community developers to monitor their locational attributes in a realistic manner, and to match these attributes with the needs of particular industries. In their development strategies, communities need to evaluate:

- their existing economic base, and identify potential linkages to appropriate high-tech sectors.
- their labor market and links to sources of quality education locally, particularly access to major universities and research institutions.

- the amenities they offer, especially access to recreational and cultural opportunities.
- their financial infrastructure, especially access to local development capital for medium size and small firms.
- access to local and national markets via different forms of transportation.

Communities which see themselves as lacking in some of these attributes would need to concentrate their development strategies on deficiencies where appropriate. Most communities would wish to foster one or more of the following: manpower assistance, technical and financial assistance and improve their access to cultural and physical amenities. Though many communities may expend many resources on such ventures, their success rate in attracting in high-technology companies will in all probability be small.

Introduction

To gain an understanding of how high-technology industrial complexes develop around the country, insights can be gained from two major bodies of theory: theories of regional economic growth and industrial location theory. Part I contains a review of the various partial theories of regional economic growth, each dealing with technological change in either an explicit or implicit fashion. From this review, the most appropriate elements of regional growth theory that helps us explain the development of high-technology complexes are identified.

Because these growth theories deal with regional develoment in a macro sense, their applicability in understanding the location patterns of industry depends on the cumulative effect of individual decision makers. Therefore, in order to appreciate the geographical orientation of high-technology industry, it is necessary to examine industrial location theory and how location factors implicit in that theory relate to high-technology industry. This is the focus of the second part of this paper.

The increasing involvement of states and cities in the competition for high-technology jobs has made it imperative that communities be aware of the location factors perceived to be important by decision makers before they develop strategies to lure high-technology companies.

Part 3 deals with ways in which communities can monitor and mobilize their local potential for attracting high-tech industries in a realistic manner. A target industry methodology is suggested as an objective way of matching community attributes with the needs of high-tech industry. Finally, the chances of success in such endeavors are examined inthe light of many communities chasing a small number of potential clients, when past development incentives have shown little evidence of success. If state policies cancel each other out in trying to attract high-tech companies into their localities, many resources could be wasted.

## 1. Regional Growth Theories and Their Relevance to Understanding the Development of High Technology Complexes.

In the same way that the relationship between technological change and economic growth remained among the "terra incognita" of modern economics until recently, regional economists and economic geographers have been slow to examine regional variations in the link between innovation, diffusion, and regional economic growth either conceptually or empirically. There is growing evidence, however, that factors influencing technological change may vary between regions in a systematic manner (Thomas and Le Heron 1975, Rees 1979, Oakey, Thwaites and Nash 1980, J.E.C. 1982).

Because of the recent advent of what Business Week called the high-technology "War between the States", it seems appropriate to review regional growth theory to try and further our understanding of the development of high-technology complexes. Though most theories that purport to explain regional economic growth do not explicitly address the role of technological change, this factor is implicit in most of the theories developed to date. These theories will be reviewed here as to how they deal with technological change and how they relate to the development of high-technology complexes around the United States.

At the outset it should be recognized that there is no single, acceptable, comprehensive regional growth theory, but a set of partial theories that explain or emphasize different aspects of the regional development process. Though there have been attempts at synthesizing these partial theories into a regional growth theory (notably by Richardson 1973) these at best are difficult to operationalize in a policy context. The theories reviewed here are therefore partial theories, each dealing with technological change in different and often limited ways.* These theories involve:

(i) the role of a region's export base

(ii) regional income convergence or divergence over time

(iii) growth pole theory

(iv) regional diffusion processes

(v) product and regional life cycles

## 1.1 Export Base Theory

Several researchers have stressed the role of exports as the initial trigger for regional growth (North, 1955, Perloff and Wingo, 1961). At its simplest, export base theory states that a region's growth rate is a function of inter-regional and international export performance.

"This ability to export induces a flow of income into the region which, through the familiar multiplier effect, tends to expand the internal markets of the region for both national and region-serving goods and services....As the regional market expands and region serving activities proliferate, conditions may develop for self reinforcing and self sustaining regional growth,

*Useful reviews of these theories are to be found in Lloyd and Dicken (1977), and Weinstein and Firestine (1978).

and new internal factors may become important in determining the rates of regional growth, such as external economies associated with social overhead capital and the agglomeration of industries, and internal economies of scale" (Perloff and Wingo, 1961, p. 200).

The resource endowments of a region are therefore seen as determining its competitive advantage over other regions, and such endowments can clearly be modified through technological change, changes in the labor force, the importation of capital and the like. For example, three individuals relocated from the Northeast in the 1930s in search for Gulf oil, initially founding Geophysical Services Incorporated. Due to the lack of indigenous technology, they devised their own instrumentation in the search for oil and this led to the birth of one of America's most successful electronics companies, Texas Instruments.

Not only can such export-producing industries result in a regional balance of payments surplus, but export industries tend to have strong forward and backward linkages with other industries in other regions, hence aiding the integration of the developing region into the national economy. Furthermore, "export industries tend to be technologically advanced and to operate at higher levels of productivity. Income generation from high-productivity industries filters through the region and helps to spur development of residentiary (non export) industries" (Weinstein and Firestine, 1978, p. 62). Hence, export base theory recognizes the higher multiplier potential of high-technology sectors, though the exact nature of such multipliers has not been the focus of much empirical work.

## 1.2 Regional Income Inequality Theories

A number of theories have been concerned with explaining regional income inequality, mostly in the context of developing countries or growth regions in more advanced economies. These theories suggest that the economic growth process, once triggered by some initial motivating force, tends to be cumulative in nature. Under this rubric, there are two major types of theories:

### 1.2.1 Factor Price Equalization Theories

The notion of convergence in regional incomes emerged from theories of international and inter-regional trade. The key assumption of these models is that factors of production--capital and labor in particular--are "free" to move in economic space to seek their point of highest return. Hence, inter-regional mobility of capital from northern to southern states in the 1970s is seen as movement from areas of low return, to areas of high return (Wheaton, 1979). Eventually, an equilibrium is reached where per capita income is equalized between regions.

Evidence shows that a high degree of regional income convergence took place in the United States over the last fifty years (Survey of Current Business, April 1977, Weinstein and Firestine, 1978). In 1929, per capita income in the Southwest was only 53 percent of the U.S. average, but by 1976 this had reached 84 percent of the U.S. average. During the same time period all but two of the industrial states of the Northeast and Midwest showed relative declines in per capita income, with drastic declines in some states, notably New York, Connecticut and Delaware. Since the Southeastern and Southwestern states have been the largest recipients of both physical and human capital over that period, this suggests that both industrial companies and individuals were seeking to maximize income, hence causing income convergence among regions.

The intra-regional pattern of capital mobility in the United States in recent times is however a complex one. "Income analysis of economic and population trends during the seventies indicates that a powerful decentralization of activity was occurring....But important qualifications need to be made about the periphery, for it was not an economic monolith" (Keinath, 1982, p. 356). Growth rates among the states of the Sunbelt South have by no means been equal, reflecting large differences in industrial structure. "The dominant industries in the Carolinas, Tennessee and Texas have included textiles, apparel and food processing--all comparatively labor intensive and low wage industries at the mature end of their technology cycles. Nearly 42 percent of the South's manufacturing employment are in low-wage industries as compared to only 20 percent for the U.S. as a whole. The South employs only about 25 percent of its manufacturing workers in high wage industries as compared to 37 percent for the United States" (Weinstein and Firestine, 1978, p. 51). The fact that regional income convergence between North and South appears to have been led historically by the decentralization of relatively low-technology industries and low-technology sectors of high-technology industries can also be explained by the regional manifestation of the product cycle model discussed later.

### 1.2.2 Unbalanced Growth Theories

While regional convergence or equilibrium theorists see the spread effects of development as the mechanism by which growth is transmitted throughout an economic system, advocates of unbalanced growth, particularly Myrdal (1957) and Hirschmann (1958), strongly dispute the effectiveness of these spread effects. Myrdal's theory of unbalanced growth centered around the notion of "cumulative causation" mechanisms where market forces tend to attract economic activity in certain areas that acquired an initial advantage through location, technology or some other factors. The buildup becomes self-sustaining, and results in very little growth in peripheral regions. Myrdal does not deny the existence of spread effects, particularly in the case of an advanced, integrated, economic system like the United States. He only argues that market mechanisms do not inevitably produce such spread effects to promote an equalization of growth imbalances.

Lagging areas are debilitated by what Myrdal calls "backwash effects", analogous to Hirschmann's "polarization" processes. From here labor and capital migrate to the growth areas of the "center", while investment levels in public service also inhibit the development of peripheral areas. Thus, according to Myrdal, the backwash effects reinforce the tendency for regional income divergence.

For both Myrdal and Hirschmann, economic developnent is a function of interaction between leading (core) and lagging (peripheral) regions. Thus, if spread (trickle down) effects are stronger than the backwash (polarization) processes, cumulative causation mechanisms will lead to the development of new economic centers and lay the foundation for future innovation growth. While recognizing the complexities implicit in the delicate balance between equilibrating and disequilibrating forces, Williamson's (1965, p. 199) definitive study of the experience of 24 countries concludes that "rising regional income disparities and increasing North-South dualism is typical of early development stages, while regional convergence and a disappearance of severe North-South problems is typical of the more mature stages of national growth and development". The recent history of America's regions tends to bear witness to this conclusion.

"Although Myrdal and Hirschmann did not have the United States in mind when referring to northern (growing) and southern (lagging) regions, their descriptions of the economic growth process sound remarkably like the American experience over the past century" (Weinstein and Firestine, 1978, p. 58). It was not until the period between 1880 and 1910 that the Northeast and Midwest developed into the dominant industrial region of the country, accounting for 72 percent of all U.S. manufacturing by 1937. Shortly thereafter, spread effects started to emanate from the industrial core, with Northern capital investing in Southern and Western agriculture and transportation, and generating the material requirements of the Manufacturing Belt. The predominance of military bases set up in the South and West, first associated with World War II if not the Civil War, had an appreciable influence on net migration flows. Between 1965 and 1970, military personnel accounted for 14 percent of inter-regional migrants and is testimony to the role that government policy can play in spread effects. More recently, plant obsolescense, and externalities such as increased congestion and pollution served as push factors for an increased decentralization of economic activity from the North. This coupled with the pull of cheaper labor, less unionization, growing markets and a perceived increase in amenities in Southern and Western states caused the process to gain momentum to such an extent that it has been interpreted as a realignment of traditional core-periphery relationships in the United States. The core region's relative decline during the 1970s can therefore be related to the cumulative effects of a gradual dispersal of innovative activity to the South and West.

## 1.3 Growth Pole Theory

Economic development theorists have recognized for some time that growth occurs initially around one or more regional centers of economic strength. Hirschmann (1958, p. 183) argues: "This need for the emergence of 'growing points' or 'growth poles' in the course of the development process means that international and interregional inequality of growth is an inevitable concomitant and condition of growth itself. Thus, in the geographic sense, growth is necessarily unbalanced".

The origins of growth pole thoery is usually traced to the French economist, Francois Perroux, whose original conception of growth poles referred to _industrial sectors_ and not their spatial manifestation. In this sense research on growth poles has been confusing. While non-geographic originally, it became transformed into a spatial concept mostly by regional planners under the term _growth center_. (See reviews by Darwent, 1969, and Hansen, 1972.) In Perroux's conceptualization, polarization depended on the growth of one or more _propulsive industries or companies_ with particular characteristics: they had to be relatively large, fast-growing, have well developed supplier and market links with other industries, and _be innovative_. Such propulsive institutions would also include universities, as witnessed by the role of MIT in the creation of the Route 128 industrial complexes. Such institutions were seen to be leaders, though sectoral polarization in this context did not necessarily imply geographical clustering. However, it is generally recognized that "there do appear to be significant spatial polarizing influences present in the working of the multiplier" (Lloyd and Dicken, 1977, p. 406). These include in particular, the operation of scale factors (specifically agglomeration economies), the spatial clustering of innovations and the nature of industrial decision making discussed in part 2 of this paper.

_Growth pole theory therefore has a more explicit recognition of the importance of the link between technological change, innovation and regional economic growth than the other theories reviewed so far_.

"Thus one may envisage the situation of a growing, successful economic system, say an industrial city, drawing to it the ideas of spatially dispersed inventors searching for sponsorship, pulling in the skills of migrants, investing its own funds in the search for invention and using its accumulating capital and labor to convert this flood of new technology into effective use (Lloyd and Dicken, 1977, p. 409). Pred shows this in the context of the American urban system at the end of the nineteenth century. "New or enlarged urban industries and their 'multiplier' effects created the employment opportunities that sucessively attracted 'active' and 'passive' migrants to the infant metropolises, and eventually led to additional manufacturing growth by directly or indirectly enhancing the possibility of invention and innovation" (Pred, 1966, p. 39). Wilbur Thompson (1968) takes this argument further by suggesting that the major advantages of large urban areas do not lie so much in their economic base in the traditional sense but rather in their capacity to innovate, as reflected in universities and research institutions with an explicit concern for creativity, again explaining the role of MIT and Stanford in the creation of Route 128 and Silicon Valley, respectively.

The tendency for entrepreneurial skill and innovation potential generally to be concentrated in large urban areas is reinforced by the organizational structure of modern business enterprises. The control functions of large industrial enterprises have become concentrated in large metropolitan areas to the extent that Stanback (1982) could recently identify a group of command and control centers within the American urban system.

Since most new businesses tend to stay in areas where their founders were initially located, it is also likely that large urban areas will spawn more new companies than small urban areas. Thus larger agglomerations serve as seedbeds or incubators for the growth of new companies (Struyk and James, 1975, Cooper, 1971, Danilov, 1972). To date very little empirical evidence exists on the way urban areas function as industrial seedbeds and how this relates to their innovation potential. Intuitively, however, one can identify a network of primary and secondary seedbeds for innovative industries that may follow the urban-size hierarchy.

There does exist evidence that the diffusion of industrial innovation may be highly related to personnel movements between firms in the same and related sectors. But verification of this process is limited and based on dated empirical studies. Many recent generalizations about the process refer to the work of Cooper (1971) on the spin-off process in the San Francisco area. Out of Cooper's work came the conclusion that small firms have higher spin-off rates than large firms. But such statements may not hold true over time (given the vicissitudes of the business cycle) nor over space. Indeed one key variable so far in receipt of little attention is the role of organizational structure and corporate policy on spin-off mechanisms. In this respect we can classify spin-off firms according to how they came about:

a. Competitive spin-offs--where employees leave a company and establish their own companies where the products compete directly with those of the initial parent. Because most buyers require a "second source," the need for duplication and standardization of products can be a major stimulus for spin-off here.

b. <u>Backward linked spin-off</u>--where employees set up their own company to supply the parent with needed materials. This may be the result of a conscious parent-company policy decision to buy rather than make a product it needs, i.e., where the spin-off is directly encouraged by the parent.

c. <u>Forward linked spin-off</u>--where employees set up a company to market products on which they worked for the parent. This may occur where an employee identifies a potential use for a product, and decides to market the idea himself. This could have a major effect on the diffusion and adoption of a particular product.

It should also be recognized that large firms can limit the number of external spin-offs by encouraging flexibility and reward for product and process innovation <u>within</u> the firm, i.e., by <u>de facto</u> encouraging internal spin-offs for risky R&D ventures with a three to five year make or break horizon. Texas Instruments has been seen as a company that finds and keeps technical entrepreneurs through its small business development schemes <u>within</u> the company. This may be one reason why the number of spin-offs in the Dallas area (where Texas Instruments is the leading electronics company) is <u>low</u> in comparison with the number of spin-offs from Fairchild in the San Francisco Bay area. To date, however, we have very little evidence on how the spin-off process works in different types of high-technology companies or industries.

In the context of growth pole theory, it is also important to emphasize that for most industries: "investment decisions tend to favor those systems in which previous investment has apparently met with favorable returns" (Lloyd and Dicken, 1977, p. 412). Large growing urban areas are powerful sources of demand for investment funds as a result of their propensity to create expanding opportunities for innovation. Hence, one would expect the larger urban areas to be the most fertile spawning grounds for high-technology industries. Nevertheless, the faster growth rates of small and medium-sized growth centers in recent years coupled with the revitalization of non-metropolitan areas suggest that powerful agglomerating tendencies are also at work in these smaller growth centers with populations between 200,000 and 1 million. Because of this shift towards what Irving Kristol called an urban civilization without cities, it is indeed possible that high-tech complexes will develop in a wide variety of different locations. For this reason, the next round of high-tech growth poles may well be away from the large agglomerations of Boston, San Francisco, New York, Dallas and Phoenix, and towards medium-sized growth centers of the country - places like Austin, Texas; Albuquerque, New Mexico; Colorado Springs, Colorado; Portland, Oregon; Lowell, Massachusetts; and the like. These are generally urban places small enough to offer a superior quality of life while still being large enough to provide necessary services and accessibility.

1.4 Diffusion Theory

Though economists (Mansfield, 1977, Gold, 1977) have undertaken numerous studies of technology transfer and the diffusion of industrial innovations, they have largely ignored the regional context of innovations. Likewise, geographers have a long tradition of concern for the innovation diffusion process (Hagerstrand, 1967, Brown, 1980), but most of their research has focused on consumer rather than industrial innovations. Thus, there exists a need to integrate appropriate elements of both economic and spatial models of innovation diffusion.

In this context, Brown (1980) has identified at least four approaches to the study of innovation diffusion:

- the adoption approach which focuses on the process by which adoption occurs, mostly as a function of the learning or communications process.
- the market and infrastructure approach, focusing on the ways in which adoption conditions are made available via diffusion agencies and adoption strategies.
- the economic history perspective which emphasizes the dynamic, evolving nature of innovations.
- the development perspective with focus on the impact of diffusion on employment and regional disparities.

From these various approaches to the study of innovation diffusion, at least four types of diffusion models can be identified:

a. the epidemic diffusion model which emphasizes distance decay factors and the logistics curve, where diffusion is seen as a function of the contact system of adopters. The "tyranny of distance" implies that the diffusion or spread of innovations is most effective in areas close to the point of origin (see part 2 for more detail).

b. the hierarchical diffusion model, emphasizing the urban-size hierarchy as the prime determinant of the diffusion process (Berry, 1972). While most initial approaches saw the format of flow filtering down the urban size hierarchy this does not necessarily imply a rigid progression from larger to smaller urban centers for all types of innovations. Pred has related this to the organizational structure of multi-locational companies:

"If diffusion influence flows inter-organizationally, or from one headquarters city to another, such diffusion need not be merely comprised of larger-city to smaller-city sequences. It may also include spread from large cities to even larger cities, from smaller cities to larger cities, or from one city of a given size to another city of approximately the same size." (Pred, 1975, p. 256).

Further, in one of the few existing studies on the interregional diffusion of industrial innovations, Martin and Swan (1979, p. 22) conclude: "If an innovation originates in an industry where the process of diffusion is governed by market structure, regional characteristics can largely be ignored. On the other hand, if an innovation is diffused according to the urban hierarchy, the regional factor becomes preponderant." Innovations in manufacturing are included in the former, while consumer innovations involve the latter.

c. The inter-industry diffusion model emphasizes the sectoral environment of a firm and the importance of contextual variables such as market structure, profitability, access to capital markets and age of capital stock in explaining the diffusion process (Mansfield, 1977).

d. The inter-organizational diffusion model focuses on the internal characteristics of firms as determinants of diffusion, together with attitudinal and information variables.

One reason why these models have not been integrated into a comprehensive diffusion theory to date relates to the fact that they operate at different levels of analysis. "The epidemic and hierarchical diffusion models strictly viewed, deal with the question of how a phenomenon develops in time and space, while only the industry-specific and firm-specific models attempt to answer the question of why a particular diffusion pattern emerges. . . . If one thus questions the influence of space on the diffusion of innovations one must proceed from both of the last-named models and investigate how the validity of these models is modified by the fact that the economic subjects are exposed to varying locational environments" (Ewers and Wettman, 1980, p. 169).

Because of operational problems implicit in this type of research, very little empirical studies exist on the inter-regional diffusion of production innovations, particularly in the

United States. One of the few studies to show that geographical variations may produce variations in rates of technological change comes from Britain and includes an analysis of data on the first adoption of significant manufacturing innovations (Oakey, Thwaites and Nash, 1980). After they allowed for regional variations in plant size structure, an analysis of the location of plants responsible for the first commercial production or application of nearly 300 major product and process innovations between 1965 and 1978 showed that the Southeast region (the "core" of the U.K.) is by far the most innovative. This region was seen to have a large concentration of headquarters functions (particularly in R&D and marketing), independent business services and the availability of specialist skills on the local labor market. Similarly, Malecki's (1980) work in the United States identified the locational concentration of R&D work in the "core" states of the Northeast and Midwest. In contrast, the industrial milieu of peripheral areas in Britain would appear to be less conducive to industrial innovation, a reflection of an industrial structure dominated by branch plants that only support a limited range of management control functions.

The exact nature of differences under the more complex regional structure of the United States is not known to date. As a step in understanding more about regional differences in innovation potential in this country a recent study of the inter-regional diffusion of new, computerized production processes in the United States (Rees and Briggs, 1983) relates the adoption of these innovations to a number of contextual variables: sectoral, organizational and geographical. A random sample of 600 manufacturing plants in the machinery and electronic industries (SIC 35 and 36) across the United States shows that adoption rates for these new technologies (computerized numerical control systems, the use of computers in commercial, design and manufacturing activities, programmable handling systems and the use of microprocessors in final products) varied significantly according to:

- the organizational status of plants, where plants belonging to multi-plant firms were much more likely to adopt than single-plant firms,
- size of plant, where larger plants had much higher adoption rates than smaller ones,
- age of plant, where the older manufacturing plants showed a higher propensity to adopt than newer plants,
- R&D (research and development) intensity, where plants with some R&D on-site or at some other location within the company had higher adoption rates.
- and by location, where plants in the older established manufacturing belt (the Northeast and North Central census regions) showed higher adoption rates than plants in the South and West. In this study, the age of plant variable shows strong evidence that the older manufacturing plants across the country have been rejuvenating themselves to remain competitive. This suggests that the innovative capacity of the older

industrial heartland of the country should not be written off in any attempt at reindustrialization or economic recovery that may be initiated at the federal level.

## 1.5 Product and Regional Life Cycles

Building on growth pole theory, and recognizing the propulsive nature of technology in changing regional economic structure, regional researchers in the 1970s turned to the product cycle model and the technology life-cycle concept for more appropriate explanations of the changing locational requirements of firms that are developing products at different stages of maturity (Thomas, 1980, Rees, 1979, Norton and Rees, 1979). Drawing on Vernon's work in an international context and Thompson's (1968) filtering down theory of industrial location the product cycle model has been used to explain recent regional industrial shifts in the United States.

Briefly, the product cycle model is based on the premise that products evolve through three distinct stages in their life cycles:

- an innovation stage where a new product is manufactured in the home region and introduced in a new market area by exports,
- a growth stage where external demand (inter-regional or international) expands to a point where direct investment in production facilities becomes feasible and when process technology can be transferred,

 (no p 27)

- o and a standardization stage when production may shift to low-cost locations.

This model has an explicit locational dimension since each stage of the product cycle has different locational requirements. The innovation stage which needs a high input of R&D is usually carried out in high-cost areas, as in the case of mini- and micro-computers in California and Massachusetts. The standardization phase on the other hand favors low-cost locations, typically peripheral areas where labor costs are cheap, and the level of unionization is low. This part of the argument explains the early loss of nearly one million production jobs from the Manufacturing Belt between 1947 and 1963. This application of the product cycle model also implies that as decentralization of production accumulates in peripheral growth centers, external economies of scale will increase in those locations, particularly agglomeration economies, service infrastructure development and local linkages. Furthermore, regional demand in the receiving regions can grow to a critical threshold where industrial growth takes off on its own though a seedbed or indigenous generation effect, e.g., large companies spawning small companies, particularly in high-technology sectors. Aiding this growth process in the new areas is the immigration of entrepreneurs. Evidence of such developments can be seen in the once-peripheral new growth centers (the Sunspots) of the South and West, as in the Dallas-Forth Worth area (Rees, 1979). This spatial manifestation of the product cycle therefore implies that over time regions can change their roles from being recipients of innovation (via branch plants) to become generators of innovation through indigenous growth.

Traditionally the Manufacturing Belt has served as the seed-bed of innovation for the American industrial system (Perloff and Wingo, 1961, Rosenberg, 1972). Using the product cycle framework, Norton and Rees (1979) argued that the diffusion of technology-intensive growth sectors to the more peripheral growth centers of the United States (like Dallas and Phoenix) means that the innovation potential of the Manufacturing Belt has been eroded and that of the periphery enhanced. Shift share analysis showed that the Manufacturing Belt was seen to specialize in nationally declining industries, whereas the positive industrial mix of peripheral areas showed a greater share of more technology-intensive growth industries (electronics SIC 36, aviation equipment SIC 372, scientific instruments SIC 38, chemicals and plastics SIC 28 and 30). While this analysis was carried out on an aggregated regional level (using Census divisions) it tends to ignore the intra-regional variations that make the Frostbelt-Sunbelt distinction a questionable one, i.e., it is more appropriate to think in terms of growth centers within the periphery (or Sunspots) as opposed to a large homogenous region like the Sunbelt.

Given the complexities of regional industrial change it is difficult to separate cyclical from structural changes during the stop-go inflation-recessionary era of the 1970s and early 1980s. Since the capital goods sector of the Manufacturing Belt was seriously hit by the Great Recessions of 1975 and 1982, it is quite feasible that cyclical changes exacerbate structural change, which may mark the 1970s as the turning point for the Manufacturing Belt as the dominant industrial core of the country. At the same time, however, it has to be recognized that the position of any region on its growth curve is the result of counterbalancing forces characterized by the push of innovation or new developments to encourage adaptation on the one hand, and the pull of inertia protecting existing structures on the other hand. Indeed, implicit in Utterback's (1979) concept of technological rejuvenation, Malecki's work on the locational concentration of R&D in the Northeast and Midwest, and Rees and Briggs' (1983) findings on high adoption rates for new production technologies within the Manufacturing Belt is that the old industrial heartland still has more indigenous potential for economic revival than is generally accepted. Evidence from the recent revival of New England is further testimony to this. "New England industry stagnated for three decades, from the late 1940s until mid 1975. . . . Since then it has sustained one of the most significant economic revitalizations in the history of market economies" (James Howell, quoted in National Journal, 2/26/83, p. 435).

Recently therefore, it has become popular once again for economists to think in terms of long cycles (or waves) of growth and decline, but this time in a regional context (Sternlieb and Hughes, 1978). This notion of a regional life cycle has its antecedents in Kondratieff's long waves and Schumpeter's notion of "creative destruction" where new economic structures in new regions bypass existing structures that become functionally obsolete. Previous extensions of the regional life cycle model include Friedmann's taxonomy of regions into frontier areas, upward transitional regions, heartlands, downward transitional areas, and depressed regions. Borchert (1967), however, explicitly recognized the propulsive nature of three major clusters of innovations and their impact on the evolution of the American urban economic system: the steamboat and "Iron Horse"; steel rails and electric power; the internal combustion engine and the shift to services. Using these innovation clusters, Borchert identified four important eras in the evolution of America's urban system:

- the Sail-Wagon Epoch 1790-1830
- The Iron Horse Epoch 1830-1870
- The Steel Rail Epoch 1870-1920
- The Auto/Air/Amenity Epoch 1920 to the present

Using the framework of regional life cycles to understand more recent developments, New England has been seen as the first Frostbelt area to enter a long economic slump, and therefore would be expected to recover first. But one has to treat such generalizations with care. "There are two economies going on in the New England states, the high-tech area but also the continuing struggle of the old mill towns" (National Journal, 2/26/83, p. 436). The large amount of part-time and low-wage jobs in the region caused Harrison to view New England as a dual economy with a "missing middle. . . . of skilled jobs within particular industries which traditionally employed the largest number of skilled and semi-skilled blue collar workers" (Harrison, 1982, p. 117).

Others are skeptical of the industrial Midwest going through the same kind of economic transformation as New England did in the last 10 to 15 years. Solutions for the Mid-Atlantic and Midwest might have some things in common with those of New England, but they are by no means identical (National Journal, 2/26/83, p. 437). High levels of unionization and relatively high wages compared to other parts of the country are the kinds of inertial factors that give reasons for skepticism about the imminent economic transformation of the Midwest. The future direction of the industrial heartland's life cycle, and reliance on high technology as a panacea for development are clearly open to question. The technological-imperative that drove the revival of New England may not be present in other areas, at least not to the same degree. However, the industrial heritage of the Manufacturing Belt, the quality of output associated with its companies, and increasing wage inflation in Southern regions may in time shift comparative advantage back to the initial heartland. Indeed, such market mechanisms may play a greater role in the rejuvenation of America's older industrial regions than the state development programs discussed in section 3.

## 1.6 The Implications of Regional Growth Theory: A Summary

Theories that explain regional economic growth deal with technological change in a variety of ways. Export base theory and regional income inequality models do not deal explicitly with the role of technological change. Yet, implicit in the application of export base models is the recognition that export industries can be more technology-intensive and therefore result in higher levels of regional productivity. Technology-intensive industries with higher amounts of output per unit labor can have higher inter-regional and intra-regional multiplier effects that can hasten the process of regional economic growth. Factor price equalization theories explain how capital and labor can flow inter-regionally to seek their highest returns, and studies of economic decentralization from North to South in recent times have related per capita income convergence in the United States to the growth of key high-technology sectors in certain regions.

The two types of regional growth theories that deal more explicitly with the role of technological change are growth pole theory and product-regional life cycle theory. The former explicitly recognizes the importance of propulsive, high-technology sectors in the urban growth process, and how such growth centers can perform as incubators or seedbeds for the birth of new industry. The application of the product cycle model to regional development on the other hand recognizes that products have different locational requirements at various stages in their development process. New product development tends to take place in R&D intensive locations where costs tend to be higher, while mass-production techniques allow the decentralization of production to lower cost locations. This technology life-cycle argument has clear implications for interpreting recent industrial shifts in the United States, as suggested by the growth of Sunspots in the South and West and by the resurgence of growth in New England.

Diffusion theory has yet to be integrated into regional growth theory. It does not explain the generation of innovation, only the determinants of its transfer. Yet the speed with which productivity-enhancing innovations spread through an economic system can be imperative in accelerating the economic growth process. Indeed, at the national level, policies that encourage the diffusion of innovations may be as important as policies to enhance the generation of innovations.

In summary, there does not appear to be a need for any new theory to explain the development of high-technology complexes. There may be a need to extend existing theory particularly on growth poles and product cycles. But this does not appear to deserve as high a priority on the regional research agenda as applications of existing theory to understand more fully the development of high-technology complexes.

## 2. Industrial Location Theory and the Location Decision Process for High-Technology Companies

The growth theories reviewed so far deal with regional economic development in a macro sense. Whether or not they are applicable to understanding the location patterns of industry is dependent on the cumulative effect of individual investment decisions and how individual decision makers react to their own perceptions of reality. Therefore, to appreciate the possible geographical orientation of high-technology industry, it is necessary to appreciate the decision making process of individual manufacturers. The decision making process is of central concern to industrial location theory.

To date, industrial location theory can be divided into two major schools of throught: least cost theory and maximum demand theory (Lloyd and Dicken, 1977, Smith, 1980). Because of dissatisfaction with the unrealistic assumptions of much of this theory, regional researchers have argued that a more appropriate understanding of business location can only be achieved by examining the location decision making process in its corporate context (see Stafford, 1980).

### 2.1 Industrial Location Decision Making: an Overview

The selection of good locations for industrial facilities is a complex process. The location of a new plant typically is a decision made by relatively few senior executives of a firm. It involves the objective and judgmental balancing of corporate goals and a variety of location factors. The specific location factors vary in relative importance according to firm, place, and time. Each situation is unique. Experience with many industrial location decisions indicates, however, that the factors most often seriously considered are access to markets, access to materials, transportation facilities, labor (especially availability and productivity), utilities, business services, taxes, and local "quality of life."

These and other location factors are evaluated individually and then relative to each other. The selection of relevant factors, and the weight assigned to each are functions of the size and type of manufacturing facility to be built, which are, in turn, a function of the firm's perceived needs. The locational search typically proceeds sequentially with a region of interest first being delimited. Subsections of the general region are then evaluated, followed by the selection of towns which meet the minimum requirements for the plant. The spatial search ends at the local scale with the selection of a specific town and the purchase of a building site within the local area. The location factors change in relative importance with each change in the geographical scale of search. (See Appendix A for additional discussion of the nature of industrial location decision making.)

## 2.2 The Location of High-Technology Industry

It is difficult to generalize about the locational determinants of any broad type of manufacturing activity because each firm, each plant and each situation is somewhat unique. This dif-

*ficulty is compounded for "high-technology" industry because there is no generally accepted definition of which types of manufacturing plants comprise the category*. The root of the dilemma is that some plants may be considered high-technology operations by virtue of the extensive use of automated, state-of-the-art manufacturing *processes*. Others may be considered high technology by virtue of their production of high-technology *products* (Figure 1). Examples of high *process* technology industries are chemicals, automobiles, and machinery. Examples of high *product* technology industries are computers, electronics, and scientific and industrial instruments. Few plants may be classified as high technology in both process and product.

FIGURE 1

Process technology

| | | Low | High |
|---|---|---|---|
| Product technology | Low | | |
| | High | | |

Plant level technology matrix (after Oakey, 1981)

High process technology plants tend to be large operations imbedded within the organizational and locational structures of mature, multi-plant firms. These plants enjoy economies of scale and standardized products which allow the utilization of advanced production techniques, e.g., robotics, to increase productivity, reduce the labor input per unit of product, and enhance uniform product quality. In general, the locations of high process technology plants are relatively little affected by the introduction of new production techniques.

The popular concept of high-technology industry more closely corresponds to those plants which produce high-technology products. In comparison with most manufacturing establishments, they tend to be relatively small, new and in the "early charter" stage of the "plant life cycle," akin to stage 1 of the product cycle model referred to in section 1. As early charter stage plants they must be very much concerned with determining their internal operating character, including the products to be manufactured, plant size and configuration, work-force composition and training, and overhead functions (Schmenner, 1982). As relatively small plants in relatively small firms they are likely to be independent, have high risks, engage in an informal, top-down style of location decision making due to lack of internal specialists, and have limited search spaces, preferring to locate new activities close to existing operations. They tend to be relatively unable to reap the benefits of large economies of scale, because they are labor intensive and their product lines change rapidly (Oakey, 1981, p. 37).

One example of an appropriate disaggregated taxonomy of innovative industries has been compiled for Massachusetts (Vinson and Harrington, 1979) using three and four digit SIC categories (where data were available), including innovative sectors in both manufacturing and services. This typology underscores an important definitional issue in recognizing a number of innovative "high service" sectors within that anomalous area known as the tertiary or service economy. The production of computer software is clearly one of the most innovative and high growth sectors. Yet in the SIC classification to date, it remains camouflaged in SIC 737, computer programming services. It could be argued that software is a manufactured product comparable to the printing industry, which is conventionally classified in the manufacturing sector. What may appear as a small definitional issue then can have important implications for comparing growth rates between the manufacturing and service sectors in various urban areas. Given the accepted definition of a post-industrial economy where services are seen to be more important than manufacturing as an engine of growth for the national economy, the implications of definitional issues loom large when they affect the generality of statements in the policy area.

Furthermore, one of the most important mechanisms behind the relative growth of regions in the future is not the definition of innovative sectors *per se*, but the supply and demand type interactions between the more innovative components of the secondary and tertiary sectors. Increases in services like electronic banking and telecommuting in themselves can creata a demand for manufactured products that may be viewed as an accelerator mechanism for the national economy, and urban areas with the highest growth potential in the future may be where the linkages between these innovative sectors are highest.

## 2.3 Location Factors That Influence High-Technology Industry

The location variables may be separated into two general types: (1) those relating to the friction of distance; and (2) those relating to the attributes of areas. Friction of distance variables are those which measure the costs of moving materials or products or people or ideas across space. These costs may be measured in terms of miles, or money, or time, or even psychologically as through ease or convenience. The second category is concerned not with how far one place is from another, but rather with the characteristics, or attributes, of those areas. Included are variables such as labor, agglomeration and infrastructure, power, water and the quality of life.

Although industrial location theory has traditionally emphasized the friction of distance variables, probably for the majority of plant locations in highly industrialized societies the attributes of area variables are now most important. This is especially so for high product technology firms because they produce high value added components for which transportation charges per unit of value are low, their input materials come from a variety of sources and locations, and their markets also tend to be spatially scattered.

The many factors which influence the location of a factory vary in relative importance from situation to situation. They must be properly considered within the context of the geography of a specific firm. Nor are they mutually exclusive; they must be handled within a relevant interdependence framework. However, it is useful, even if somewhat artificial, to consider the major factors separately.

Table 1 indicates the relative importance of the ten most important location variables according to various ranking schemes, by high-technology and non-high-technology plants, and by location decisions at the regional and within-region scales.

### 2.3.1 Labor

Regardless of the differences in data collection techniques, and regardless of the scale of the location decision, labor stands out as the most important of the industrial location determinates. There is now a general tendency for most firms to emphasize the labor variable in the location search for a new plant. This is especially so for high-technology plants. A survey by Stafford (1983) asked decision makers to indicate the location factors considered in the recent selection of a branch plant location. Of the 104 usable replies 57 are for high-technology operations. Stafford's study found that 79 percent of those responding for high-technology plants mentioned labor as an important factor, and this was the only factor mentioned for more than half the location decisions. Similarly, in a Joint Economic Committee Staff Study (1982) on the "Location of High Technology Firms and Regional Economic Development" fully 89 percent of the respondents indicated that labor skills/availability was Significant or Very Significant at the regional scale, with 96 percent the comparable figure for the within-region scale location decision. While labor costs are of some importance, it is clear that the availability, attraction and retention of skilled, technical and professional personnel are the primary concerns when high-technology firms locate or expand production facilities. These United States survey results are consistent with those obtained by Oakey in the United Kingdom. Oakey (1981) states unequivocally that for the location and growth of British high-technology industries, labor is the critical factor. The single most important factor is the firm's existing labor force. Even highly skilled labor tends to exhibit a high degree of spatial inertia; in this sense, high-technology industries are not locationally "footloose" because they are constrained by the uneven spatial distribution of relatively immobile labor. The research and development centers of large corporations are most often located in urban areas which are rich in information, skills and management (Malecki, 1980); so, too, are the highest technology manufacturing activities oriented toward cosmopolitan environments.

### 2.3.2 Academic Institutions

Studies within the United States context by Deuterman (1966), Gibson (1970), and Premus (JEC, 1982) indicate the importance to high-technology industries of nearby colleges and universities, especially those which focus on scientific and technical education.

These establishments of higher education are directly influential because they are repositories of technical information and they train the needed engineers and technicians. They also are important in attracting and retaining those skilled workers who wish to avail themselves of additional educational opportunities. Furthermore, to the extent that new high-technology firms are spin-offs from existing enterprises, they are more likely to be started and successful in the technology rich environments spawned by nearby universities. Oakey's (1981) United Kingdom evidence did not produce such strong ties between technical information contacts as suggested by the United States evidence, but this may be explained by a greater tendency of British firms to internalize important research activities, and by the much smaller spatial scale within which the firms operate. The importance of nearby academic institutions within the United States context is consistent with the overwhelming locational importance of skilled labor, as are the quality of life, and cultural amenities variables.

### 2.3.3 Quality of Life; Amenities

For all industries, the human factor has become a more important locational variable in the past two decades. For some it has meant a search for low cost labor areas, but for high technology it has made those areas which are attractive to highly skilled workers more productive environments. Quality of life and the existence of sufficient amenities, both cultural and recreational, are difficult variables to measure, but there is little doubt that they are critical in locational decision making. (Stafford, 1980, p. 100.) In Table 1 these include not only "quality of life" and "proximity to amenities," but also "academic institutions," and "proximity to good schools" categories. A plant started in a community which ranks low on the livability scale will soon have difficulty in attracting, or even transferring, engineers and managers. (Schmenner, 1982, p. 38.)

2.3.4 Markets Access; Materials Access; Transportation

Industrial location theory traditionally has emphasized the costs of moving materials to the plant and products to consumers. These friction of distance considerations are relatively unimportant for high-technology firms. High-technology product companies produce items for which transportation costs are a small proportion of delivered price; transit time is more critical than cost. They also utilize a wide variety of inputs which are not conveniently localized; thus, the advantages of locating near any one supplier are neutralized by the distances separating them from other suppliers. High-technology plants are not materials oriented. Transportation is a factor of some locational importance, but more in terms of the availability of requisite modes and frequency than in terms of costs. High-technology firms are more cognizant than most manufacturers of the necessity of easy access to high level, rapid transportation facilities (e.g., air travel) for the movements of managerial and technical staff. Market Access is a variable of moderate importance to high-technology plants, but again the emphasis is on ease and speed rather than cost. Relatively easy access to customers is important when the sale contract calls for service, and when there are significant reciprocal information transfers.

### 2.3.5 Taxes

Within the industrial location literature, no issue is more debated than the influence of taxes on site selection. The decision makers tend to frequently note the importance of regional and local tax differentials in practical location decisions. Analysts, however, usually conclude that taxes are of relatively little importance, especially when regions of interest are being determined. A leading consultant to corporations suggests that industrialists often use taxes as rationalization for their opposition to labor unions and other costs, real or imagined, in a region. They tend to associate all these with an unsatisfactory regional image. Regardless, based on his company's studies, the consultant concludes that "it is apparent that in every case state taxes are the least significant of all factors." (Hunker, 1974, p. 139.) Schmenner (1982), after examining both sides of the controversy, comes down firmly on the side of taxes being a relatively minor locational variable. Stafford (1980, p. 109) contends likewise, noting that a large part of the difficulty in resolving the issue is that taxes are as much an emotional issue as a financial issue. For high-technology industries, the debate also continues. Schmenner (1982, p. 50) notes that low taxes may be somewhat more valued by high-technology industries since they are less locationally constrained by other factors (e.g., markets and materials access). The Joint Economic Committee (JEC) survey indicates that taxes are the second most important locational determinant for high-technology firms, ranking just after labor considerations (Table 1). Stafford's recent survey evidence, however, places taxes as a minor locational variable (Table 1). The discrepancy may be partly attributable to differences in the questionnaires; whereas the JEC questionnaire asked an explicit question on taxes, the Stafford survey simply asked the respondents to list the several factors important in their recent location decisions. When asked directly about the influence of taxes in the JEC (1982) study, 67 percent indicated that taxes are Very Significant or Significant at the regional scale, with the within-region scale figure rising to 85 percent. By contrast, in the free-response Stafford survey (1983) only 14 percent of the high-technology respondents even mentioned taxes as a location factor. The issue remains unresolved. Further complications are introduced when it is noted that low taxes usually are negatively spatially correlated with several other areal attributes which high-technology firms value, such as the provision of public services, infrastructure, good schools and cultural amenities.

### 2.3.6 Financial Capital

Though the availability of financial capital is one of the key variables that influence R&D trends and innovation generation, very little is known about geographical differences in the availability of financial capital. Historically, the industrial location literature (e.g., Smith, 1980) has assumed a uniform surface of accessibility to financial capital. This assumption has become part of the status quo without appropriate empirical testing. Given the different banking systems evident in the U.S. at present, ranging from branch banking to unit banking as modified by multibank holding company acquisitions, an isotropic plain of access to capital may be a faulty assumption. This is particularly the case in the current context of deregulation in the financial sector, with the trend towards a national branch banking system already in existence (de facto) in many states that allow loan production offices for non-local banks, and the growing banking interests of large retailing concerns previously prohibited from banking activities.

Because of the important role that access to venture capital can play in the generation of innovations, particularly in small companies which have higher risks attached to them, spatial and temporal variations in access to capital may be a factor of significance yet to be shown. Katzman (1982) reminds us of this when he reports of a study for the U.S. Economic Development Administration on the difficulties that 2000 companies reported in obtaining a number of capital instruments, ranging from lines of credit to common equity. Many of the results of the survey are intuitively predictable: companies with higher debt to equity ratios had more difficulty obtaining capital than firms with lower ratios; smaller firms had more difficulty than larger firms. Though no major differences were seen in risk factors and debt ratio associated with central city or suburban located companies across the U.S., rural companies did appear to have greater difficulties in obtaining capital, presumably a reflection of the more conservative traditions of rural banks. However, when firms were classified by census region there were few discernible differences in difficulties in obtaining capital (Katzman, 1982:33).

In a recent study of the relationship between financial capital and innovation in small firms in the U.K., Oakey (1982) shows a heavy reliance on internally generated profits as the principal source of funding for further investment. This is partly due to the behavior of small firms traditionally minimizing their own risks when considering external loans, as well as risk aversion on the part of external borrowers. It was also found that the use of internal profits was much higher in small firms in low-technology sectors, suggesting that small firms with the highest innovation potential are more aggressive seekers of external funding. However, the greatest use of internally generated capital was made by small firms in the economic core of the U.K., the Southeast, paradoxically seen to be the most innovative region in general (i.e., when large firms are also included) while more innovative firms in the peripheral regions turned more towards external funding.

Though most of the small firms surveyed had not received any government aid from various programs eligible for small companies, evidence from the U.K. suggests that the availability of regional development grants in peripheral regions may act as a direct stimulus to obtaining additional aid from national (i.e., non-region specific) development schemes for small businesses. This suggests that many small businesses are not aware of development schemes that they are eligible for, and this may be true in the American context as well. Without empirical testing of these types of issues in the United States, it will be impossible to sort out the myths from the realities of small business generation in this country.

## 2.4 Summary

1. Most firms go through the location search and decision process in much the same sequence. So do high-technology companies, both those utilizing high-technology processing and those producing high-technology products.

2. Labor is now the most important locational variable for many industries. This is especially true for high-technology products plants where the availability of a skilled labor pool is critical. High-technology firms have higher than normal demands for technicians and engineers. Several other key location variables also relate to the human factor. Important are the quality of life in an area and the existence of good schools and universities for the training, attraction and retention of skilled workers and managers.

3. No fundamental alterations to existing industrial location theory are necessary to accommodate the spatial search and

decision processes of high-technology plants. High-technology firms place greater emphasis on the attributes of area variables than on the costs of moving materials to the plant or products to customers, but these can be accommodated by proper weighting of the relevant variables.

4. Regional and local organizations can most likely enhance the probability of the location and growth of high-technology industries in their areas by the support of direct skilled labor training and retraining, and the more general support of quality education. Since companies producing high-technology products tend to have a great deal of locational flexibility, financial inducements may be necessary to compete with other similarly attractive areas. Care must be exercised, however, to guard against excessive inducements wherein the host area does not receive benefits commensurate with the longer term provision of high quality services, infrastructure, schools and amenities. Awareness and consideration of the specific concerns of existing activities within an area are important since high-technology growth appears to be a localized, circular and cumulative process. The pros and cons of what states and cities can do to nurture their high technology potential is the focus of part 3.

Table 1. Location Factors Influencing New Manufacturing Plants

A. High-Technology and Non-High-Technology Plants

| Rank | High-Technology Plants | Non-High-Technology Plants |
|---|---|---|
| 1 | Labor | Labor |
| 2 | Transportation Availability | Market Access |
| 3 | Quality of Life | Transportation Availability |
| 4 | Markets Access | Materials Access |
| 5 | Utilities | Utilities |
| 6 | Site Characteristics | Regulatory Practice |
| 7 | Community Characteristics | Quality of Life |
| 8 | Business Climate | Business Climate |
| 9 | Taxes | Site Characteristics |
| 10 | Development Organizations | Taxes |

H.A. Stafford Survey of 104 Plants (1983).

B. High-Technology Plants According to the JEC Questionnaire (1982)

| Rank | Selection of Region | Selection Within Region |
|---|---|---|
| 1 | Labor Skills/Availability | Labor Availability |
| 2 | Labor Costs | State/Local Tax Structure |
| 3 | Tax Climate Within Region | Business Climate |
| 4 | Academic Institutions | Cost of Property/ Construction |
| 5 | Cost of Living | Transport Availability for People |
| 6 | Transportation | Ample Area for Expansion |
| 7 | Markets Access | Proximity to Good Schools |
| 8 | Regional Regulatory Practices | Proximity to Amenities |
| 9 | Energy Costs/Availability | Transport Facilities for Goods |
| 10 | Cultural Amenities | Proximity to Customers |

## 3. Towards an Evaluation of High-Technology Development Programs for Cities and States

Because of the increasing involvement of states and cities in intense competition for high-technology jobs, it has become even more important recently for communities to be aware of location factors perceived to be important by decision makers. Hence, therse exists a need for areas to monitor their attributes in a realistic fashion and to match them up with the factors of importance to industry (as discussed in part 2) in their area development programs.

### 3.1 The Need to Monitor and Mobilize Local Potential

Regardless of incentive packages offered over the next few years and however areas vary in their attractiveness for high-tech manufacturers, there will be an intense competition for a few selected high-technology industries, and the job creation potential at the end may still be low. "Forecasts made by the BLS. . . show that the number of high-tech jobs created over the next decade will be less than half of the 2 million jobs lost in manufacturing in the past 3 years. . . . While dollar output in high-tech industries will grow by 87 percent over the next decade (from 7 percent of GNP to 10 percent). . . the number of workers needed to produce this increase will need to rise by only 29 percent" (Business Week, 3/20/83, p. 85).

Because rewards may be small and the game highly competitive, there is a need for each locality to monitor its existing potential in order to establish realistic goals for the attraction of high-tech industries. One of the most effective tools to be used in this regard is the target industry screening method developed by the Battelle Institute (1970). Developed initially as an alternative to the "shotgun-approach" often taken by communities in their marketing efforts, the screening matrix method provides a more systematic method for matching the attributes of communities with the needs of industry (Sweet 1970). The screening approach assumes it is important that future industry be related to the existing economic structure of an area in terms of industry linkages and resource base. This recognizes the importance of current attributes of an area in attracting further industrial development, as implied by export base and growth center notions in part 1.

Using this screening method, industries with the greatest number of desirable attributes are identified as the highest order prospects for an area. In order to evaluate candidate industries, weights are assigned to the locational criteria of industry based on careful consideration of an area's comparative advantages and current economic conditions. Clearly such weightings can have a high degree of subjectivity associated with their choice. The types of locational criteria that should enter the screening methodology in the context of high-technology industries should include the following factors discussed in parts 1 and 2 of this paper:

- an area's existing economic base, particularly the presence of high-tech sectors or companies with direct links to high-tech sectors. This approach could include input-output analysis and would identify potential industries for import substitution.

- <u>the scientific and technical environment</u>, including access to major universities and research institutions.
- <u>labor factors</u>, including occupational mix (proportions of professional, skilled and unskilled workers), labor cost and productivity as they relate to the labor intensity of existing industry.
- <u>financial variables</u>: including local property and income tax rates, the role of commercial banks, savings and loan banks and other financial institutions with access to development capital.
- <u>amenities</u>, particularly access to recreational and cultural opportunities.
- <u>access to local and national markets</u> via different forms of transportation.

It is only through systematic monitoring that one can assess the comparative advantage of an area for attracting specific industries. A <u>regional marketing plan</u> should, however, look out for conflicting goals. For example, it is conceivable that industries with a high propensity to attract in suppliers (backward links) may result in the clustering of many industries that could put further demands on certain types of labor. This in turn could result in higher rates of wage inflation in the area, which may prove unattractive to other industries.

In summary, therefore, an understanding of an area's industrial base plus an objective screening process is one of the few sound ways of attracting future economic development, whether technology intensive or not. Without such systematic procedures, community resources may be wasted.

## 3.2 The Pros and Cons of High-Technology Development Incentives

The National Journal (2/26/83) recently put some perspective on the media attention that has accompanied the rush of states into the high-technology development business. "Industrial policy (implying high-technology development strategies for cities and states-author) is not a new idea. Most states and large cities have had one for years, though they may have called it 'economic development'. Whatever it is called, it boils down to doing whatever governors, mayors and civic leaders can to keep current employers and attract new ones" (National Journal, 2/26/83, p. 434). Since it has become fashionable for states to instigate policies that may create another Route 128 or another Silicon Valley, the chances of doing so are remote indeed. This is so for two reasons at least:

1. The factors that contributed to the development of both these aforementioned hi-technology growth poles are unique. To understand the growth around Route 128, one has to recognize the historical preeminence of MIT among the country's science and technical universities, and to understand policies there that encouraged the spin-off of graduates and faculty to start their own

companies. The history of Silicon Valley on the other hand would have been very different if William Shockley (the inventor of the transistor at Bells Labs) had not returned to his home town of Palo Alto. Here again the high degree of clustering of companies in a confined geographical space meant that informal communication between workers encouraged personnel mobility and spin-off from the lead companies: Hewlett Packard, Fairchild and the resulting "Fairchildren." (Braun and MacDonald, 1979.)

The third glamor story portrayed by the media, that of Research Triangle Park in North Carolina, is 25 years old and took at least ten years to get off the ground. Though North Carolina witnessed a high-technology employment growth of 52 percent from 1975 to 1979, this only amounted to 29,000 extra jobs. This equals the absolute increase in high-technology employment in Minnesota over the same period, but falls behind the growth of high-technology sectors in New York State (33,000), Florida (37,000), Texas (28,000), Massachusetts (54,000) and inevitably California (154,000).

2. The second reason why one can be skeptical about the success of these high-technology development programs is to be found in their incentive structure. As suggested in Section 2, most research on economic development over the past fifteen years has found only minimal evidence that manufacturing industry's locational choices across the United State is influenced to any significant degree by taxation policy at the state or local level. Yet, looking around the country, state and local governments seem

to suggest that they can influence industrial location development in their regions. "This is evidenced by the fact that 45 states offer tax-free state and local revenue bond financing to industry; 29 states offer other types of low interest loans; 25 states do not collect sales tax on newly purchased industrial equipment; 38 do not levy inventory taxes on goods in transit; virtually all states have industrial development agencies; and many state and local governments offer tax credits, abatements, and rapid depreciation to encourage new investment in plant and equipment" (Weinstein and Firestine, 1978, p. 134). The net effect of all this is that most state programs cancel each other out in the eyes of the industrialists, and there is a danger that fiscal incentives, or even venture capital incentives towards high-technology industries on a small scale would cancel each other out if offered by many states. If services offered to new, expanding or relocating high-tech industry are indeed not much different from services offered to more traditional industry, then the chances that state incentives cancel each other out will be high indeed.

Though there is but limited evidence on how high-technology companies respond to fiscal stimulii compared with manufacturing as a whole, PREMUS' recent survey of location determinants among high-technology firsm (JEC, 1982) showed that a region's tax climate was listed as the third most important locational factor (behind labor skills and costs) in the choice of region, and second (behind labor availability) in the locational choice within regions. "The potential mobility of their technical and professional employees, upon which they place so much dependence, probably accounts for the sensitivity of high-technology companies to state and local taxes" (JEC, 1982, p. 34). This may be true, but the hypothesis needs more rigorous testing among workers with different skill levels. From this one study, one can accept that state and local taxes _may_ be one of the more important locational factors considered by high-technology companies. But the results of such surveys in the past have also shown that what people say and do at two different points in time do not amount to the same thing.

All this does not imply that state programs will not have any success in attracting hi tech industries. The _type of package_ is important as well as the size of incentives, and the states with the biggest incentive packages will probably win. The types of programs already in existence include:

- o _technical assistance_ in the form of access to equipment, information dissemination, management planning and technical feasibility studies,
- o _manpower assistance_ including co-operative retraining programs between the private and public sectors,
- o and _financial assistance_ in the form of access to risk capital for small firms (i.e., via state equity investment, loan guarantees, or development banking),

These types of programs are more likely to be successful than conventional fiscal packages, though many are still skeptical about the possibility that they cancel each other out as the number of states entering the High-Tech War between the States increases (Schmenner 1982). In the last analysis, the concern of high tech companies for access to appropriate labor, the perceived importance of access to superior local universities and a high regard for enhancing the quality of life of their employees would appear to take priority in the companies' locational calculus over any diversion caused by state or local investment subsidy.

## 4 REFERENCES:

Advisory Commission on Intergovernmental Relations (1980), Study of Interstate Competition for Industry, Washington, D.C.

BATTELLE Institute (1970), The Regional Potential Model, Columbus, Ohio.

BERRY, B. J. L. (1972), Hierarchical Diffusion: the Basis of Development Filtering and Spread in a System of Growth Centers, in N. HANSEN (ed.), Growth Centers in Regional Economic Development, New York: Free Press.

BORCHERT, J. R. (1967), American Metropolitan Evolution, Geographical Review, 57, 301-332.

BRAUN, E., and S. MCDONALD (1979), Revolution in Miniature, London.

BROWN, L. (1980), Innovation Diffusion, London: Methuen.

CAMPBELL, R. M., and D. HITCHIN (1968), "The Delphi Technique: Implementation in the Corporate Environment," Management Services, November-December.

CARLTON, D. (1979), Why New Firms Locate Where They Do, in W. WHEATON (ed.), Interregional Movements and Regional Growth, Washington, D.C.: Urban Institute.

CHAMBERLAIN, N. W. (1968), Enterprise and Environment: The Firm in Time and Space, New York: McGraw-Hill.

COHEN, K. J., and R. M. CYERT (1965), Theory of the Firm: Resource Allocation in a Market Economy, Englewood Cliffs: Prentice-Hall.

COOPER, A. C. (1971), "Spin-Offs and Technical Entrepreneurship, IEEE, Transactions on Engineering Management EM-18.

DANILOV, V. J. (1972), Research Parks and Regional Develoment, in A. C. COOPER and J. L. KOMIVES (eds.), Technical Entrepreneurship: A Symposium, Milwaukee, pp. 96-107.

DARWENT, D. F. (1969), Growth Poles and Growth Centers in Regional Planning: a Review, Environment and Planning, 1, pp. 5-31.

DEUTERMAN, E. P. (1966), "Seeding Science Based Industry," New England Business Review.

EWERS, H. J., and R. W. WETTMAN (1980), Innovation-Oriented Regional Policy, Regional Studies, 14, pp. 161-180.

FRIEDMANN (1972), Urbanization, Planning and National Development, Beverly Hills, California: Sage.

GIBSON, L. James (1970), "An Analysis of the Location of Instrument Manufacture in the United States," Annals, Association of American Geographers, Vol. 60, No. 2.

GOLD, B. (1977), ed., Research, Technological Change and Economic Analysis, Lexington, Massachusetts: D.C. Heath.

HAGERSTRAND, T. (1967), Innovation Diffusion as a Spatial Process, Chicago: University of Chicago Press.

HANSEN, N. (1972), Criteria for a Growth Center Policy, in A. KUKLINSKI (ed.), Growth Poles and Growth Centers in Regional Planning, The Hague: Mouton.

HARRISON, B. (1982), Rationalization, Restructuring and Industrial Reorganization in Older Regions: The Economic Transformation of New England Since World War II, Working Paper #72, Joint Center for Urban Studies, MIT-Harvard University.

HIRSCHMANN, A. (1958), The Strategy of Economic Development, New Haven: Yale University Press.

HUNKER, H. L. (1974), Industrial Development, Lexington, Massachusetts: Lexington Books, D.C. Heath and Co.

Joint Economic Committee (1982), Location of High Technology Firms and Regional Economic Development, Washington, D.C.: USGPO.

KATZMAN, M. (1982), The Case Against Bailing Out Distressed Areas, in S. REDBURN and T. BUSS (eds.), Public Policies for Distressed Areas, Lexington Books.

KEINATH, W. (1982), The Decentralization of American Economic Life: An Income Evaluation, Economic Geography, 58, pp. 343-357.

KRUMME, G. (1969), "Towards a Geography of Enterprise," Economic Geography, Vol. XLV, No. 1.

KUKLINSKI, A. (1967), Criteria for Location of Industrial Plants, Secretariat, The United Nations, New York.

LLOYD, P., and DICKEN, P. (1977), Location in Space: A Theoretical Approach to Economic Geography, New York: Harper and Row.

MALECKI, E. (1980), Corporate Organization of Rand D and the Location of Technological Activities, Regional Studies, 14, pp. 219-234.

MANSFIELD, E., et al. (1977), The Production and Application of New Industrial Technology, New York, W. W. Norton.

MARTIN, F., and N. SWAN, et al. (1979), The Interregional Diffusion of Innovations in Canada, Ottawa: Ministry of Supplies and Services.

MYRDAL, G. (1957), Rich Lands and Poor, New York: Harper and Row.

NELSON, R., and S. WINTER (1977), In Search of a Useful Theory of Innovation, Research Policy, 6, pp. 36-76.

NORTH, D. (1955), Location Theory and Regional Economic Growth, Journal of Political Economy, 63, pp. 243-258.

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

OAKEY, R., A. THWAITES, and P. NASH (1980), The Regional Distribution of Innovative Manufacturing Establishments in Britain, Regional Studies, 14, pp. 235-254.

OAKEY, R. P. (1981), High Technology Industry and Industrial Location Aldershot, England: Gower Publishing Co., Ltd.

OAKEY, R. (1982), Finance and Innovation in Small Firms, Discussion Paper, University of Newcastle, U.K.

PERLOFF, H., and L. WINGO (1961), Natural Resource Endowment and Regional Economic Growth, in J. SPENGLER (ed.), Natural Resources and Economic Growth, Washington, D.C., "Resources for the Future."

PRED, A. (1975), Diffusion, Organizational Spatial Structure and City-System Development, Economic Geography, 51, pp. 252-268.

REES, J. (1979), Regional Industrial Shifts in the U.S. and the Internal Generation of Manufacturing in Growth Centers of the Southwest, in W. WHEATON (ed.), Interregional Movements and Regional Growth, Washington, D.C.: Urban Institute.

REES, J., and R. BRIGGS (1983), The Diffusion of New Technology in American Manufacturing Industry, Working Paper, Maxwell School, Syracuse University.

RICHARDSON, H. (1973), Regional Growth Theory, London: MacMillan.

ROSENBERG, N. (1972), Technology and American Economic Growth, New York: Harper and Row.

SCHMENNER, Roger (1982), Making Business Location Decisions, Englewood Cliffs: Prentice-Hall.

SMITH, D. M. (1980), Industrial Location, London: John Wiley.

STAFFORD, H. A. (1980), Principles of Industrial Facility Location, Atlanta: Conway Publications.

STAFFORD, H. A. (1983), The Effects of Environmental Regulations on Industrial Location, Working Paper, University of Cincinnati (project funded by N.S.F.

STANBACK, T., and T. NOYELLE (1983), Economic Transformation in American Cities (in press).

STERNLIEB, G., and J. W. HUGHES (ed.) (1978), Revitalizing the Northeast, Rutgers: New Jersey: Center for Urban Policy Research.

STRUYK, R., and F. JAMES (1975), Intrametropolitan Industrial Location, Lexington Books.

SWEET, D.C. (1970), An Industrial Development Screening Matrix, Professional Geographer, May, pp. 124-127.

THOMAS, M., and R. LE HERON (1975), Perspectives on Technological Change and the Process of Diffusion in the Manufacturing Sector, Economic Geography, 51, pp. 231-251.

THOMPSON, W. (1968), Internal and External Factors in the Development of Urban Economies, in H. PERLOFF and L. WINGO (ed.), Issues in Urban Economies, Baltimore: Johns Hopkins Press.

TIEBOUT, C. (1957), "Location Theory, Empirical Evidence and Economic Evaluation," Papers and Proceedings of the Regional Science Association, Vol. III.

TOWNROE, P. M. (1971), Industrial Location Decisions, A Study in Management Behavior, University of Birmingham (U.K.) Centre for Urban and Regional Studies, Occasional Paper 15, pp. 17-27.

UTTERBACK, J. (1979), The Dynamics of Product and Process Innovation in Industry, in C. HILL and J. UTTERBACK, Technological Innovation for a Dynamic Economy, New York: Pergamon Press.

VINSON, R., and P. HARRINGTON (1979), Defining "High Technology" Industries in Massachusetts, Department of Manpower Development, Commonwealth of Massachusetts.

WEINSTEIN, B. L., and R. FIRESTINE (1978), Regional Growth and Decline in the United States, New York: Praeger Publishers.

WHEATON, W. (1979), ed. Interregional Movements and Regional Growth, Washington, D.C.: Urban Institute.

WILLIAMSON, J. G., (1965), Regional Inequality and the Process of National Development: A Description of the Patterns, Economic Development and Cultural Change, 13, pp. 3-45.

## 5 Appendix A: Further Background on the New Plant Location Decision

Industrial location decisions can be classed as in-site or new-site. In terms of absolute change, in-site decisions are by far the most important. Sixty to 80 percent of new manufacturing capacity each year is allocated to expansion of existing plants and only something under 40 percent to the construction of new ones (Kuklinski, 1967). In-site expansions and contractions are clearly locational decisions; they are decisions not to make these changes elsewhere.

However, for an existing firm, the construction of a new plant is a drastic response to excesses of demand over capacity, one to be considered only after every effort has been made to wring additional production out of existing facilities, or to obtain a new, more efficient labor force, or to establish new production procedures. Thus, in-site location decisions are usually routine, low-level, short-run decisions where location is relatively passive, with other factors of the production process being dominant. New-site decisions, on the other hand, necessarily make location considerations explicit. These decisions are made by the management for relatively longer periods of time. They are the strategic decisions.

The time span for new plant construction and the length of the amortization period that follows are significant. These factors, plus the magnitude of the investment, clearly make the decision part of the long-range planning process of the corporation. There is the conscious effort to forecast and to control the future. On the other hand, given the many variables other than location which influence revenues, and the financial resources of modern manufacturing facilities, the time period is too short for these forces to be fully operative. No doubt the majority of new manufacturing locations are both planned and non-optimal. Clearly, then, a key pattern in the understanding of industrial location patterns is an inquiry into the decision-making process.

Since new-site selection is a management decision, many persons are involved. Either maximum profit or satisfactory profit may be valid general objectives, but neither presents an operational basis for choosing among alternative location strategies. The evaluation of future states of affairs, and therefore prospective returns, would differ among the several evaluators involved in the management decision. Even if all seek maximum (or satisfactory) profit, but each concludes that it can be obtained by a different route, there is no test of rightness. There is no objective basis for judgment (Chamberlain, 1968). Likewise, multiple decision makers need to reduce the influence of purely personal considerations. No one person, not even the President or the Chairman of the Board, has the power to site a plant solely on the basis of a personal whim.

It is likely that the location decision mechanism is objectively, if not psychologically, rather simple, because, "resource allocation within the firm reflects only gross comparisons of the marginal advantages of alternatives. Rules of thumb for evaluating alternatives provide some constraints on resource allocation, and there is no conscious comparison of specific alternative investments. Any alternative that satisfies the constraints and secures suitably powerful support with the organization is likely to be adopted." (Cohen and Cyert, 1965, p. 338). Furthermore, forecasts are necessarily rather abstract; and, "as forecast needs vary from the concrete to the abstract, the importance of empirical data diminishes rapidly; also, forecasters with specialized skills must be replaced by informed generalists, capable of operating without empirical evidence but with disciplined imagination to evaluate diversified sources of qualitative information." (Campbell and Hitchin, 1965, p. 39).

The decision process is implemented by the individual firm's top management team, and we may postulate that a primary goal is the growth of the firm. Although precise establishment of the cost and revenue curves may be important for classic, normative economic models, the time horizon for new plant construction and the uncertainty of the future discount their influence on actual location decisions. Detailed information on the past of a firm or industry establishes a frame of reference for seeking and evaluating relevant data; but it does not answer questions about the future. Rather, the reality is that decision makers must rely on experience, intuition, generalized trends and readily available data to guide the location decision.

Following are some general principles upon which location decision makers seem to operate:

1. The location problem is not a common concern; rather, it most often becomes explicit when it becomes clear that additional or different productive capacity is necessary. The capacity problem is usually immediate, and the first solution is in-site expansion, through increasing production from existing facilities (for example, multiple shifts), and then by expansion by construction of additions to the existing plant. Only after these short-run solutions prove inadequate or unreasonable is a new facility in a new location seriously considered.

2. The majority of new plant location decisions are made in response to the need for additional capacity. Thus, the existence and location of markets are of importance in the location of industries (this is true even for the so-called "materials-oriented" and "footloose" industries).

3. The speed with which a firm responds to capacity demand varies according to the quality, scope and nature of this firm's growth guidelines. Organizations used to expansion tend to develop specific growth plans and also tend to move more quickly from the in-site to the new plant solution to additional capacity demands than firms with more modest growth rates (or, in some cases, with larger economies of scale).

4. Decision makers rapidly and drastically transform the infinite complexities of the optimal location problem into a relatively simple, intellectually manageable situation. This

is normally accomplished by allowing the current and projected spatial demand surfaces (i.e., market maps) to be the prime determinates in defining the geographic decision space. The regional space so defined is further simplified by the judgmental selection of a finite (and small) number of specific sites for detailed consideration. At this sub-regional scale, cost factors are paramount.

5. Decision makers also simplify and control their environment by not indulging in difficult modes of analysis when the payoffs are unclear or unsure. Likewise, they tend to avoid, when possible, implementation of any solution which entails arduous negotiation with such groups as unions and governmental regulatory agencies.

6. The ultimate decision is made and/or ratified by the highest levels of management. They view the new plant location decision as a relatively long-run solution but one which must rely on good data for relatively short-run projections. It is this discrepancy, the uncertainty of the future, which necessitates judgmental, rather than technical, decision making.

7. Although location decision makers make no claims for economic optimality, the decision process is viewed as logical and rational. There is no firm which cannot cite the rationale for its plant location(s). In this sense, there is no such thing as a "foot-loose" plant (or industry).

Although each locational decision differs in detail, investigation suggests striking similarities in the decision-making process. In every case, there was a judgmental response, in the face of uncertainties, to an immediate need of the corporation. The decisions were made by relatively few persons in upper management, were seen as an integral part of the total financial decision process of the firm and were reached relatively quickly. Especially noteworthy were the rapidity and severity with which the scope of the spatial search was circumscribed and relative lack of overt, detailed feedback to the decision makers about the correctness of the location decision after the fact.

The decision processes noted tend to conform to more general models and are examples of Chamberlain's (1968) "strategic decisions," Tiebout's (1957) "adaptive processes" and Krumme's (1969) "spatially active" decision making. They fit closely Townroe's (1971) decision stages of (1) development of management policy, (2) pressure for changes in space, (3) pressures for a new site, (4) the search for a new site.

Strong common denominators among the case studies suggest the following generalized trace of the locational decision process:

1. Identification of need. New facilities are usually constructed to meet expanded product demand, to obtain more modern plant and facilities or to escape an unfavorable labor situation. The nature of corporate need influences the spatial search process.

2. Corporate preconditions. The vast majority of the world's possible locations are never explicitly considered in the search process. Most are precluded by preconditions

imposed by the corporate situation. These may be subdivided into:

(i) Organizational preconditions, such as "we only consider one plant at a time" or "we are determined to escape the jurisdiction of our present union."

(ii) Spatial preconditions, such as "we avoid overseas locations," or "we have always been in Ohio," or "we already have plants in those areas."

3. <u>The Spatial search</u>.

(i) Selection of an area of search, at the subnational or, more commonly, the regional scale. The preconditions provide at least vague limits to this area: it is usually centered on, or adjacent to areas of current production and within areas of current distribution. This first spatially overt decision stage involves the rather precise, and usually arbitrary or impressionistic, delimitation of the specific area of search.

(ii) Focus on a subsection of the regional area of search. This stage is reached relatively rapidly. The decision process may involve the utilization of area development agency and utility company data, but, in general, it seems to be primarily based on the very limited regional knowledge and impressions of the part-time location decision makers.

(iii) Selection of a set of towns. In this stage, a preliminary survey of the selected sub-region identifies those towns which promise to supply the minimum requirements for the plant, such as sufficient population size, good labor potential or adequate accessibility. The number of towns so selected for more detailed consideration is usually very small, normally less than six.

(iv) Selection of a specific town for the plant through the analysis of objective data and the subjective impressions of the decision makers. This, and the immediately preceding stage, consumes most time and effort in the spatial decision process. Since one criterion for selecting a town is the desirability of a specific site, the town selection process very often also determines the site selection.

4. Ratification of the location decision. The location decision by the working managers normally must be ratified by the uppermost policymakers of the firm, such as the Board of Directors and the President. So long as the location decision makers are creditable, approval is usually routine.

5. Construction and operation of the plant. After the start of production at a given site, little thought is given to the correctness of the location decision, except when a specific decision is used to model a subsequent decision. There is also a great tendency to rationalize the decision since the location chosen is recognized as permanently fixed for a long duration. Except in extreme situations, there is

an effort to amortize the building and location in spite of changes in the corporate or competitive situation which may diminish the viability of the location. The plant is adapted to change.

Having established that industrial location decision making is a complex interweaving of diverse strategies and goals, are there any overarching principles that may be advanced at this point? Three pairs of opposing forces may be recognized.

First, there is the fundamental tension between economies of scale and the friction of distance. Large economies of scale dictate larger, fewer, more widely separated plants. High friction of distance (transportation) costs dictate smaller plants located in a finer, more dispersed spatial network. Larger plants may be more internally efficient, and, in the aggregate, easier to manage, but transport costs are higher, single investments are larger, flexibility is reduced, and the risks of a poor locational choice are greater. The converse is true for a network of more but smaller plants. The trick is to balance correctly these opposing forces; the correct solution will be different for each firm and each geographical area.

Second, there is the analytical dilemma of deciding whether to emphasize a least-cost solution or a maximum demand locational pattern. Although in theory it is obvious that maximum profits are a function of both revenues and costs, in practice it is not easy to reconcile the two basic approaches. Once again, the trick is to get the correct balance.

Third, there is the problem of planning for the short-run versus the long-run. A firm that does not plan for the future may well find itself in untenable locations far too quickly; on the other hand, if current needs cannot be met, there may be no future to worry about.

# PART II:

# THE ADOPTION OF NEW TECHNOLOGY IN THE AMERICAN MACHINERY INDUSTRY

John Rees
Ronald Briggs
Raymond Oakey

## SUMMARY

This study examines the spread of a number of key production technologies among machinery manufacturers across the United States. The techniques under study all relate to automation within manufacturing and include machine control systems, the use of computers, handling systems and microprocessors. The following findings are based on a questionnaire and interview survey of 628 industrial plants in various regions of the country.

1) Plants affiliated to multi-plant firms show much higher rates of adoption for these technologies than single-plant firms. Larger plants also show consistently higher rates of adoption.

2) Older plants are more likely to adopt these new technologies than newer plants. This shows that for an integral part of this country's industrial economy, the machinery industry, older plants across the country have been rejuvenating themselves to remain competitive. This suggests that older manufacturing plants cannot be written off as users of out-dated technology. Indeed the results of the study are testimony to the inherent potential of older plants to increase their technological sophistication.

3) Some important regional differences are evident in innovation adoption patterns. Adoption rates for computerized numerical control (CNC) systems are highest in the industrial Midwest, while user rates for more traditional handling systems are higher in the southern states. These findings suggest that the innovative capacity of the old industrial heartland of the country should not be overlooked in any attempt by the federal government to encourage economic growth.

4) Though adoption rates for these new technologies are higher in urban compared to rural areas, large urban areas are not necessarily the most conducive environments for companies that use the latest available technologies.

5) Significant regional differences in adoption rates among single-plant firms suggest that such firms located close to areas where the technologies were developed are more likely to use these innovations. For policy-makers at the state or federal level interested in nurturing small business, this suggests that some attention be given to a technical assistance strategy that encourages the spread or diffusion of innovation among small firms.

6) For users of computerized machine control systems (particularly CNC) the study identified problems in acquiring skilled labor. Such shortages may indeed act as an incentive to the greater adoption of automated production, though the introduction of advanced production systems like CNC required retraining the existing labor force. These findings are further evidence that policy-makers in both the private and public sectors need to give high priority to labor training and retraining programs in their economic development strategies.

# INTRODUCTION

During times of low economic growth it is inevitable that regional patterns of growth and decline become more conspicuous. Any attempt by the federal government to encourage economic growth at the national level cannot afford to ignore the differing regional endowments of the United States, the fact that key growth industries develop within or may be attracted to certain types of locations, and that the economic growth process may be related to regional variations in innovation potential. Evidence from other studies suggests that the future development of low growth regions such as the American Manufacturing Belt will be heavily dependent on the ability of industry in such areas to raise their level of technological progress through the adoption of new product and process technology (Premus, 1982; Thwaites, 1978; Ewers and Wettman, 1980).

The purpose of this study is to investigate the spread of selected new production technologies across the United States. All these technologies are related to computerized automation within manufacturing and may have substantial impact on employment levels in the long run both in terms of new and existing jobs. The project examines differences in the adoption levels of these production innovations according to a number of explanatory variables: type of industry, affiliation to a single- or multi-plant company, age and size of plant, the amount of research and development undertaken, and the regional and metropolitan locations of plants. The study involves a survey of nearly 4000 manufacturing plants throughout the United States. The results of the study enable us to answer a number of questions on the adoption of these innovations.

As the United States gears up for economic recovery after a prolonged period of recession, and as the structure of the economy continues to change, this study identifies factors that may encourage the spread of new technologies throughout American industry. Because this study is part of an international collaborative effort, we will also be able to compare technology adoption levels in the United States with those of the United Kingdom and the Federal Republic of Germany.

## RESEARCH DESIGN

### Choice of Technologies

In order to facilitate inter-regional and international comparisons, a discrete number of product and process innovations within manufacturing were selected as the focus of investigation. All the innovations relate, directly or indirectly, to computerized automation within manufacturing and represent a set of techniques at differing levels of sophistication that may have a significant long-term impact on the American labor force and on productivity levels (Premus, 1982). The innovations selected relate to four main areas of production technology: machine control, the use of computers, handling systems and the use of microprocessors.

The specific techniques examined are:

- numerical machine control (NC) devices
- computerized numerical control devices (CNC)[1]
- computers used for commercial activities only e.g. invoicing, stock control, accounting

[1]NC machines are controlled by programs expressed in numbers, and are predecessors (on the road to fully flexible automation in manufacturing) of the more flexible and versatile CNC systems which are the equivalent of NC machines equipped with programmable computers.

- computers used for design and drafting activities
- computers used in manufacturing (excluding CNC)
- programmable handling systems for materials and subcomponents, including numerically controlled pick-up-and-place devices and simple programmable robots
- non-programmable handling systems for materials and components, including manual and non-programmable pick-up-and-place devices
- the use of microprocessors, mini- and micro-computers in the final product of a plant.

The first six production techniques relate directly to increased automation in the production process. Non-programmable material handling systems were included to isolate plants with more traditional handling devices. The use of microprocessors in the final product was the only product innovation examined..

## Selection of Potential Adopters

The selection of innovations for study and the choice of industries as potential adopters were inter-related issues because the choice of innovation suggests particular sectors, for example, the use of NC and CNC suggests the metal-working machinery industry. Furthermore, to limit the scope of the study, and to facilitate inter-regional and international comparisons, it was necessary to clearly delineate a number of industries (by 3 and 4 digit SIC classification) as candidates for adopting the above innovations. The choice of a limited number of target sectors also acts as a control for industrial structure and how it influences technology utilization levels.

The six target sectors chosen[2] were producers of:

- farm machinery (SIC 3523)
- construction and related machinery, including elevators, conveyors, cranes, industrial tractors (SIC 3531, 3534, 3535, 3536, 3537)
- metal-working machinery for cutting and forming (SIC 3541, 3542)
- electrical distributing equipment, including transformers and switchgear (SIC 3612, 3613)
- electrical industrial apparatus, including motors, generators and welding equipment (3621, 3623)
- aircraft and parts, including engines (3721, 3724)

Most of the target population of potential adopters, amounting to 94 percent of respondents, were machinery manufacturers (SIC 35 and 36). Thus, the study was restricted to integral parts of the capital goods sector.

Survey

A postal questionnaire was sent to 3873 individual manufacturing plants in the target sectors employing over 20 people as identified in the DUNS files of the Dun and Bradstreet Corporation* (1976). The questionnaire was sent out between February and April 1982 to all plants across the US identified in the DUNS files as producing goods with the above SIC codes. This ensured extensive geographical coverage of the

---

[2]The first five sectors were standardized with the British and German studies using the international SIC coding system. The aircraft industry was only included in the American study.

*Though the accuracy of Dun and Bradstreet data has been questioned in studies of job creation, it remains the best national directory of manufacturing establishments available on computer tape.

United States, as suggested in Table 1. Plants employing less than 20 people were left out of the survey because past research has shown high death rates and lower response rates from this group.

A total of 628 completed responses were obtained. When undelivered questionnaires were discounted (either because the plant had moved to an unknown address or gone out of business) this response represented an adjusted rate of 19.6 percent. This response rate is particularly good when compared with other studies of this kind when success depends on the cooperation of busy corporate executives.

The national mail survey was supplemented with more detailed evidence from a limited number of telephone interviews with plant managers in two contrasting regions of the country: the East North Central and West South Central Census divisions. Evidence from this survey will be presented after analyzing the results of the mail survey in order to offer further insights into the innovation adoption process.

Because a major purpose of this study was to examine regional differences in innovation adoption across a limited number of industrial sectors, it was particularly important that respondents to the mail survey represented a random geographical sample. The random nature of respondents to the mail survey are confirmed in tables 2 and 3. Table 2 shows the distribution of the total population of potential adopters together with responses received in all nine Census divisions of the United States. A chi square statistic of 13.12 shows no significant difference between the proportion of responses compared to the total population i.e. the responses were random geographically. A further check in Table 3 shows the distribution of the population and responses according to the metropolitan character of the counties in which respondents were located, using the size and adjacency based classification of metropolitan counties developed by the United States Department of Agriculture (Beale, 1977). Again in Table 3 a chi square value of 13.4 shows that responses were random according the their metropolitan distribution.

## RESULTS

Tables 4 through 10 show the rates of adoption of the eight technologies according to the various characteristics of the manufacturing plants surveyed. Adoption rates (percentages) are displayed and chi square tests were run on the absolute number of adopters per cell.

### Adoption Rates by Industrial Sector

Table 4 shows adoption or user rates by industrial sector, using the 3 digit SIC code of the US Census. Thus, of the 132 makers of agricultural machinery in Table 4 20 percent had adopted numerically controlled machines in their production process. When differences in adoption rates are analyzed by industry, using a chi square test, there are statistically significant differences (Table 4) in the adoption patterns, but only for five out of the eight technologies. These differences are discussed below according to the four major groups of techniques surveyed.

#### (i) The Use of Machine Control Systems

The use of numerically controlled machinery varied from a 20 percent adoption rate among producers of agricultural machinery to a 68 percent adoption rate among aircraft manufacturers. The same general pattern is true for the use of computerized numerically controlled machinery.

In four of the six industries the adoption rate for CNC was higher than that for NC, suggesting that companies who had adopted NC also opted for the more advanced production technology. CNC is a major step in what Nelson and Winter (1977) call the natural trajectory of technological evolution from, in this case, manual control systems to advanced forms of automated production.

The aircraft industry stands out as the major user of both NC and CNC largely because the Department of Defense, and the US Air Force in particular, have played a major role in the development of automated production through its ICAM i.e. integrated computer-assisted manufacturing program (National Research Council, 1981).

The metal-working machinery industry has adoption rates over 50 percent for both NC and CNC systems probably because companies in that industry were the most directly involved in the generation of that technology (Rosenberg, 1972).

(ii) The Use of Computers

When adoption rates for the use of computers for commercial activities are examined by sector, no statistically significant differences are evident. Adoption rates greater than 60 percent of all plants are evident in all six industries, and reach 82 percent in the aircraft industry. This is not an unexpected pattern, given that one might expect most companies today to use computers on site in their non-manufacturing activities, for accounting, invoicing, or payroll functions.

When one examines the use of computers for design on the other hand adoption rates are much lower and the difference between sectors is statistically significant. Again, the aircraft industry is the most innovative in its adoption of computers for design purposes (51 percent), while the makers of farm machinery are the least innovative here. The use of computers in the manufacturing process per se (excluding CNC) is more widespread than for design, but a statistically significant pattern is not evident between industries.

(iii) Handling Systems

The rate of adoption of programmable or computerized handling systems is low in all sectors, with user rates below 10 percent in five out of the six industries (the exception being aircraft). Because the development of robotic handling systems is still in its infancy this pattern is not unexpected. On the other hand, the use of non-programmable (i.e. manual and mechanical) handling systems is more widespread throughout all the sectors in Table 4 with five out of the six showing adoption rates above 40 percent.

(iv) Use of Microprocessors in Final Products

The use of microprocessors as components in the final products of the plants surveyed (a product as opposed to process-oriented innovation) shows statistically significant differences between sectors. The most innovative sector in this regard is the metal-working machine tools industry, which has increasingly used microprocessors in its products over time, as shown by the development of computerized numerical control systems by the industry. The second largest user of microprocessors is the aircraft companies, who use microprocessors, mini- and micro-computers in their instrumentation and control systems.

Adoption Rates by Organizational Status

Table 5 shows adoption rates for each of the eight technologies under study according to the affiliation of the plants; whether they are part of a multi-plant firm (MPF) or a single-plant entity (SPF). A striking pattern emerges, which is both consistent for all the technologies and statistically significant in each case. Plants which are affiliated to multi-plant corporations have much higher rates of adoption than single-plant firms. For numerically controlled machines, the use of computers in design and manufacturing, and for programmable handling systems, adoption rates among multi-plant companies are double what they are for single-plant companies. This may not be surprising when one considers the financial resources available to multi-plant firms, as suggested by the economies of scale implicit in such industrial enterprises.

This does show that multi-plant companies are more innovative in their introduction of new process technology than single-plant companies. Though data on company size (as measured by total sales or assets) were not obtained directly in this survey, multi-plant companies are inevitably larger than single-plant firms. From Table 4, therefore, it can be inferred that larger multi-plant enterprises are more likely to adopt the latest available process innovations than are smaller single-plant companies. It should be recalled, however, that small firms tend to specialize in product rather than process innovations (Utterback, 1979).

These findings do however, run contrary to the popularized notions that small, single-plant companies are relatively more innovative than their larger counterparts for all kinds of technologies, and point out the importance of distinguishing between product and process innovations.

In sorting out the myths from the realities of small business innovation generation in the future, it is worth considering the cautionary words of a recent Brookings study:

> Among the common, if not universal, beliefs is that the small business sector is a powerful force for technological innovations...the difficulty with these beliefs is that they are based on a very limited amount of knowledge about the dynamics of small-business activities, as well as incomplete data (Armington and Odle, 1982, 14).

Adoption Rates by Size of Plant

Though data were not collected on corporate size, the fact that the study was conducted at the level of the individual plant does allow us to address adoption rate differentials by employment size of plant. Again, a consistent and statistically significant pattern emerges for seven out of the eight technologies. As seen in Table 6 larger plants in the survey show consistently higher rates of innovation adoption than smaller plants.

Table 6 uses the employment size classification of the Economic Census, and shows consistently higher rates of adoption for all but one of the technologies as one progresses from plants in the 20 to 99 employment size category to plants employing 1000 or more. In the design of this survey plants employing less than 20 employees were not included in the survey population. Forty responses in the 1 to 19 employment size category were returned because the survey was sent out during one of the deepest recessions of this century and employment levels had been recently reduced.

The increase in adoption rates for these technologies as one progresses up the plant size scale is highly consistent, ranging from 25 percent adoption of NC in the 20 to 99 employment category to 83 percent adoption for plants employing over 1000. The only exception to this progression is the use of non-programmable handling systems. Higher adoption rates among smaller plants in this case is understandable when one considers that this type of technology can include simple, manual material handling systems (fork lifts etc.) which are cheaper to use in small plants.

Adoption Rate by Age of Plant

The results in Table 7 show the least expected and perhaps the most provocative findings to come out of this study. A priori we expected to find newer plants to be more innovative in their use of new technologies than older plants. Our findings however show the reverse to be the case, and this pattern is both consistent and statistically significant for six of the eight technologies. On the whole, older plants are more innovative users of new process technologies than the newer ones. For NC and CNC machine control systems, and for the use of computers in commercial, design and manufacturing activities, manufacturing plants built prior to 1939 show higher adoption rates than do plants built after 1940. Indeed, when age of plant is compared by decade, a progressive inverse relationship exists between the age of plants and their propensity to adopt new technologies.

These results therefore show conclusive evidence that in a key part of the durable goods sector older manufacturing plants across the country have been rejuvenating themselves to remain competitive. Much of this retooling can be explained by the fact that most of the new technologies are discrete units that can be introduced into a plant in an incremental fashion. For example, a CNC system can be introduced into an existing plant for metal cutting or metal forming without a massive reorganization of total plant layout. This is particularly true of computers used in commercial or design activities. The results clearly imply that older plants in the United States cannot be written off as users of out-dated technology. The results are also testimony to the inherent potential that older plants may have for increasing their technological sophistication.

One other explanation for the patterns evident in Table 7 lies in the consolidation or rationalization procedures that may have been experienced by some of the multi-plant companies surveyed. During times of recession or organizational restructuring it is possible that one or two plants within a multi-locational system may have been closed and the best available technology consolidated in an older plant. Yet this trend would have been a major one among most of the 628 respondents to account for the consistent patterns seen in Table 7.

The only exceptions to the patterns seen in Table 7 are for non-programmable handling systems and the use of microprocessors in final products, where no statistically significant differences in adoption rates are seen by age of plant. Adoption rates for manual and non-programmable handling systems do not vary much by age of plant for the same reasons that they do not vary by size of plant i.e. such systems are used by most plants. As for the use of microprocessors in final products, older plants are relatively more innovative users than are the newer plants, but not to a statistically significant degree. The exception here lies in higher adoption rates (28 percent) for plants built in the 1960s, when microprocessors in American industry went through a major growth period.

The results of Table 7 do however point to the importance of differentiating between age of plant and age of capital stock when assessing the technological sophistication of American industry. Indeed, the potential among older plants for using the best available or practical process technologies can be directly related to the product cycle argument for regional industrial change developed elsewhere (Rees, 1979; Erickson and Leinbach, 1979). Since most newer plants are likely to be branch plants, the product cycle argument suggests that branch plants produce more mature products using standardized process technology. The standardization of production implies a lesser need to introduce more feasible processes like CNC, whose flexibility is better suited to the early types of product development in older plants.

Adoption Rates by Research and Development Intensity

Table 8 examines variations in adoption rates according to whether research and development (R & D) activity is conducted in the manufacturing plants surveyed. This allows us to test whether or not the more R and D intensive plants are more likely to use new technologies. From Table 8 we see that 505 plants, or 80 percent of the total, performed some form of R and D activity on site, while only 87 plants or 14 percent of the total had no R and D activity on site. Largely because of the high proportion of plants with R and D on site no statistically significant differences in adoption rates were found for five out of the eight technologies relative to the presence or absence of R and D.

For users of computers in commercial activities 70 percent conducted R and D at the same location, i.e. they were more R and D intensive. For users of computers in the manufacturing process per se, 59 percent conducted R and D at a separate location within the firm. Significant differences in adoption rates also emerge for users of microprocessors in their final products. This last pattern does show that the more innovative users of microprocessors in their final products had a substantial amount of R and D on site, a pattern that might be expected from the creative nature of such endeavors when much on-site work would have been needed to apply the microprocessors to existing or new products.

For five of the eight techniques, plants with R and D activities located at some other sites within the corporate system showed the highest adoption rates. Because of the large number of respondents with R and D on site, adoption rates were also examined according to the number of R and D workers as a proportion of total employment at each plant. A table of results is not included here because the trends seen are very similar to those in Table 8. Only 75 plants (12 percent of total respondents) had R and D workers that amounted to 5 percent or more of total employment at that plant, while only 21 plants reported over 10 percent of their workers as R and D personnel.

## Adoption Rates by Region

One of the major goals of this project was to examine differences in innovation adoption by geographical region, based on the hypothesis that plants in various parts of the country might show variations in their propensity to adopt the latest technology. Table 9 shows variations in adoption rates by Census region, based on a random response pattern. Though statistically significant differences in adoption rates only appear for two of the eight technologies, there are some important regional differences in the adoption rates for the various innovations.

Regional differences in the adoption of CNC are statistically significant, with the North Central region showing an adoption rate of 47 percent, followed by the Northeast, the West and the South. The high adoption rate for CNC in the North Central region may be expected from the region's industrial base which includes the largest industrial states of the Manufacturing Belt (Michigan, Ohio, Illinois) and the area's role as the historic center for the machine tools industry (Rosenberg, 1972). The North Central region also has the highest adoption rate for NC, where (as might be expected) the adoption pattern by region is similar to that for CNC. The North Central region also shows the highest adoption rate for the use of computers for commercial activities.

In the case of computers for commercial activities however, regional variations in adoption rates are very small. Since the use of computers for commercial purposes did not show statistically significant differences by sector (Table 4), it is not surprising that major regional differences do not show up. Plants in all four regions of the US show adoption rates above 60 percent for the use of computers in commercial activities. It is perhaps more surprising that regional differences in the use of computers for design purposes, as well as for manufacturing, are not larger.

Adoption rates for programmable (mostly robotic) handling systems are low by region as they are by sector. Regional variations in the use of non-programmable handling systems on the other hand are distinct and statistically significant. In this case it is the Southern region which shows the highest user rate and the Northeastern states the lowest rate. The high adoption rate in the South is testimony to the continued dominance of the region by branch plants (Hansen, 1980), despite the rapid growth of certain growth centers in the Sun Belt states (Rees, 1979). Regional differences in the use of microprocessors in final products are not statistically significant. The dominance of the Northeast in this case is testimony in part to the development of mini- and micro-computers in areas such as Boston (Dorfman, 1982).

Given the size and diversity of the United States it may not be surprising that a complex pattern of regional differences in the adoption of new technologies is forthcoming in Table 9. When an average ranking of regional adoption rates is carried out for seven of the eight technologies (non-programmable handling systems are left out because of their lower technology base), the dominance of the Manufacturing Belt as an user of the latest available process technology does stand out. The North Central region ranks highest, followed by the Northeast, the West and the South. Though such rankings should not be overemphasized, it does point out that despite the relative growth of the South and West in the last 15 years, this does not imply that industries in the growth regions are more prominent users of the latest available technology. Indeed, as suggested by the age of plant variable in Table 7 it is the older industrial regions of the North Central and Northeastern parts of the Manufacturing Belt that display the highest propensity to use new production technology. Thus, the innovative capacity of the older industrial heartland should not be overlooked in any attempt at reindustrialization or economic recovery that may be initiated at the federal or state level.

Adoption Rates by Metropolitan Location of Plants

Table 10 shows adoption rates according to the metropolitan character of the counties in which respondents are located. The four-fold division of counties in Table 10 includes:

- **large metro** implying counties within SMSAs of over 1 million people
- small metro defined as counties within SMSAs of less than 1 million
- urban implying nonmetropolitan counties that include at least one city with over 10,000 population
- and rural including nonmetropolitan counties with no city over 10,000 people.

Table 10 shows statistically significant differences in adoption patterns for only two of the eight technologies: numerical control, and the use of microprocessors in the final product. The adoption rate for NC is highest for plants in the smaller SMSAs, not the largest, while the lowest adoption rates occur in the rural areas. This same pattern is also true for plants using microprocessors in their final products. Indeed, adoption rates in the largest urban agglomerations are highest for only five of the eight technologies, and they are only marginally higher for two of these: CNC, and programmable handling systems. This therefore suggests that the largest urban areas are not necessarily the most conducive environments for companies that use the latest available technologies. The adoption rates seen in Table 10 do suggest that smaller SMSAs and to a large extent, the more urbanized of the nonmetropolitan counties are also conducive environments for the adoption of these new production technologies. For three of the eight technologies (computers for commercial and manufacturing activities, and non-programmable handling systems) the more urbanized nonmetro counties show the highest adoption rates. Though the larger SMSAs still show the highest average ranking for all technologies bar non-programmable handling, the more urbanized nonmetro areas show the second highest ranking, followed by the smaller SMSAs and then the more rural areas.

## FURTHER ANALYSIS OF REGIONAL AND METROPOLITAN ADOPTION PATTERNS

Thus far, statistically significant differences in the adoption patterns of new production technology were evident by industry type, organizational status of plants, size and age of establishments, and their R and D intensity. Regional and metropolitan differences in adoption rates did not come out to be statistically significant in most cases, though clear differences in the proportion of adopters are reflected in tables 9 and 10.

Despite the lack of statistically significant differences in adoption patterns by region and metropolitan type at this level of analysis, it is still important to inquire whether differences in adoption rates do come out at a more disaggregated level of analysis when differences in industry size, organizational status, R and D intensity, age and size of plants are examined between regions and between different types of metropolitan areas.

Some significant differences do indeed come out at this level of analysis as shown in tables 11 through 16. One methodological problem with analysis at this disaggregated scale involves the use of chi square tests for showing statistical associations between cells where expected counts are less than five. Because of this, results presented here are limited to a set of dichotomous variables that show statistically significant results.

## The Role of Industrial Structure

Since the industrial structure of a particular locality has a major influence on the adoption of new technologies, this was controlled for in the research design when the target sectors were sampled geographically in proportion to their share of the total number of plants in the various SIC codes. Nevertheless adoption rates in any of the six target industries (Table 4) could be significantly different in one region compared to another. Such differences were examined at both the three and four digit SIC level for all the target sectors but results were not statistically significant. Adoption rates for one of the three digit sectors, the construction machinery industry, are reported in Table 11. No statistically significant differences are to be seen at the .05 level. This also holds for adoption patterns by type of metropolitan county.

## The Influence of Organizational Status

When regional adoption rates are examined by organizational status (Table 12) statistically significant differences are evident between regions for single-plant firms adopting three key technologies: NC, CNC and microprocessors in the final product. These findings are important in that they show small, single-plant firms in the industrial heartland (the Northeast and North Central regions) to have far greater adoption rates for NC and CNC than similar firms in the Southern and Western Census regions. Likewise the use of microprocessors in final products is more prevalent in single-plant firms in the Northeast and Western regions than it is in the Midwest or South. It is no coincidence that in the case of CNC, most of the early development work was spawned in the Manufacturing Belt, whereas in the case of microprocessors in products, Massachusetts and California firms appear to have been the most progressive in the development of mini- and micro-computers. For single-plant firms therefore, this suggests a distance-decay or contagious spread effect in adoption patterns where adoption rates are lower in regions furthest removed from the spawning-grounds of these leading-edge technologies. Because of the comparative advantage that multi-plant firms have in spreading new production technologies in a variety of locations within their corporate system, it is not surprising that multi-plant firms in Table 12 show much less regional variations in adoption rates for all the technologies studied.

The distance-decay effect for single-plant firms does not appear as statistically significant however when metropolitan and nonmetropolitan adoption rates are compared in Table 13. Adoption rates for NC and microprocessors are higher for plants in metropolitan areas than in nonmetropolitan counties. Table 13 also shows adoption rates for NC and microprocessors to be significantly higher in metropolitan areas for multi-plant firms, showing that these key technologies are more likely to be introduced in urban rather than rural plants of multi-locational firms. Presumably the more sophisticated labor force associated with urban rather than rural locations would be a major factor in the introduction of these relatively complex technologies.

## The Influence of Plant Size

Table 14 shows regional adoption rates by size of plants, using employment levels below 100 to define smaller plants and employment levels of 100 or more to define larger plants. Regional adoption rates are not significantly different for any of the techniques except CNC among the smaller plants. For smaller plants using CNC however, adoption rates in the industrial heartland (the Northeast and North Central regions) are significantly higher than in the South and West. This suggests that the argument made earlier regarding single-plant firms also pertains to smaller plants. Regional differences in the adoption rate of small plants are also evident for NC and microprocessors, but are not statistically significant.

## Differences Due to Age of Plant

Because of the significant trends portrayed by the age of plant variable at the national level (Table 7) regional and metropolitan differences in this variable are further explored in tables 15 and 16. Here a dichotomous variable is used to define older plants as those established before 1960 and newer plants as those founded in 1960 or later. From Table 15 significant regional differences in adoption rates are evident for older plants using NC and CNC. Again, the role of the Northeastern and Midwestern states as the wellspring of machine tools technology comes out, with adoption rates among pre-1960 plants being much higher in the North Central region than in the South. Regional differences in the adoption of these technologies do not appear as statistically significant for plants set up after 1960, reflecting the spread of those production innovations into other regions.

User rates for non-programmable handling equipment also reveal statistically significant regional differences for older plants, showing the plants of the South and West to be the most frequent users. This reflects the more traditional handling systems that one may expect among the branch plants of peripheral regions in the South and West.

When adoption rates for older and newer plants are examined by their urban and rural locations (Table 16), the only statistically significant differences appear for newer plants introducing two innovations: numerical control, and microprocessors in product. Again these newer technologies are more likely to be introduced in the more sophisticated labor markets of metropolitan areas rather than nonmetropolitan locations. Unexpectedly in these cases, the same pattern does not hold for the older plants.

## RESULTS OF INTERVIEW SURVEY

The following section provides further insights into the types of plants involved in the adoption of production innovations based on a limited telephone survey of 37 adopters and non-adopters of CNC. The surveys on which the following data are based were carried out to provide additional perspective on the adoption process and to provide comparisons with surveys carried out in Germany and Britain. Plants in the East North Central and West South Central Census divisions of the United States were chosen because these regions represented contrasting growth environments. Though the East North Central region has recently shown symptoms of industrial stagnation while the West South Central region has experienced high rates of economic growth, Table 9 showed us that the former region was the most innovative in terms of the adoption of process technology while the latter region can be categorized among the least innovative.

Taken alone, the interview sample (n = 37) is of limited analytical relevance in a full statistical sense. However, the survey allows us to compare plants with distinct regional and innovative differences and to provide further insight into the attributes of innovative plants. The most interesting evidence to emerge from the interview survey relates to the labor force and production technology, and these are discussed below.

## Labor Patterns

The interview questions on labor revealed several features. First, it is enlightening to note that in a form of analysis that categorized firms both by region and their propensity to adopt CNC systems, problems with the acquisition of skilled labor were strongly prevalent in the category of non-adopters in the East North Central region. Of the nine firms in this category, seven admitted that they had experienced shortages of skilled machinists (Table 17). This result may be significant in that it suggests that shortages of skilled machinists in the East North Central region may act as a spur to the greater adoption of CNC systems evident in earlier analysis and in turn may help to explain both the reduced problem in firms that have adopted CNC, and the lower incidence of CNC adoption in the West South Central region where skilled labor shortages did not appear to be a particular problem.

Second, there was evidence from the survey of a much higher incidence of retraining in the CNC adopting firms in both regions (Table 18).

Although cell numbers are low, eight of the nine East North Central firms adopting CNC had retrained their workforce compared with one firm out of nine in the same region that had not introduced CNC. Such a pattern of results suggest that CNC cannot be introduced without a significant reorganization of manpower resources on the factory floor. However, other evidence indicates that, from a labor relations viewpoint, the reorganization takes place with little workforce resistance. Only one of the 37 firms in the survey acknowledged that the introduction of new production techniques on the shopfloor disrupted production through disputes.

Production Technology

The production methods of the survey firms shed valuable light on the type of plant likely to introduce CNC, while also indicating contrasts between the two regions. To a question inquiring if survey plants used assembly line methods in their plant an interesting pattern of CNC adoption emerged. Of the CNC adopters in the East North Central region, eight of the nine plants concerned did not use assembly line production compared with three out of seven adopters in the West South Central region (Table 19). Moreover, it is evident that this pattern is not replicated by non-adopters of CNC. For example, in the East North Central region six of the nine non-adopters used assembly line production.

This result is of particular interest because, contrary to some popular beliefs, CNC is not readily associated with mass production. Indeed, flexibility and the ability to re-program the computer control system is a major CNC selling point which is clearly not synonymous with mass production. The low incidence of assembly line production among East North Central plants adopting CNC compliments the earlier results of this paper which indicated that CNC adoption was prevalent in older production units common in the East North Central region. The results of Table 9 may hint at an overall pattern of production that involves the developmental stages of production in the East North Central 'core' region or more generally in the Manufacturing Belt, while more mature products are more readily found in the periphery, typified by the West South Central region. These results compliment this view in that they suggest that CNC is associated with firms not practicing assembly line production methods and that this is predominantly an East North Central phenomenon.

From this survey there is further evidence on regional differences in the introduction of CNC and its predecessor, NC, although it should be emphasized that CNC has not made NC obsolescent. Earlier evidence in this paper has indicated that the Manufacturing Belt has performed well in terms of process innovation through CNC adoption and this trend gains further support through Table 20. Eight of the nine CNC adopters in the East North Central region had previously adopted NC machines. Furthermore, this pattern does not seem prevalent in either the West South Central adopters, nor the non-adopters of either region. Indeed, the adoption of the less sophisticated NC machines in the West South Central sample of CNC non-adopters was particularly low involving only two out of twelve plants. Such a result adds to the argument that there is a high incidence of CNC adoption in the Manufacturing Belt, as suggested by earlier results of this paper. It also suggests that when numbers are controlled and roughly equal numbers of CNC adopters are considered, as in the case between a Manufacturing Belt and peripheral region, Manufacturing Belt adopters appear more sophisticated both in terms of the nature of their production (Table 19) and their 'track record' on innovation (Table 20).

The remaining point of interest concerning production relates to future intentions regarding CNC purchase. While Table 21 indicates a high level of intention regarding future CNC purchase generally, it is again clear that the incidence of such intentions is lower in the West South Central category with only two of the eleven plants indicating an intention to introduce CNC in the future.

The overall pattern of results from the interview survey builds a picture in which the East North Central innovators of CNC are generally more sophisticated than the West South Central innovators, while the West South Central non-innovators appear more 'backward' than their East North Central counterparts. While the West South Central region has a growing electronics sector, particularly in Texas, much of the industry on which these data are based related to mechanical engineering in general and the metal-working machine tool sector in particular where CNC using systems are particularly appropriate. In such sectors of manufacturing, the West South Central region appears to display many of the characteristics of a peripheral manufacturing economy.

It may be that the linked concepts of corporate control and product life cycles may well help to explain much of these results. If the Manufacturing Belt of the US is taken as the core area for the mechanical engineering sector, it is consistent with product life cycle theory that products in their 'youth' are more likely to be produced at or near the center of corporate control (Oakey, Thwaites and Nash, 1980). In these early stages CNC systems are clearly more applicable due to their great flexibility, both in terms of program adaptability and range of functions. This phenomenon may well explain the Manufacturing Belt's higher incidence of CNC adoption and lower incidence of assembly line production among the CNC adopters surveyed.

As production becomes more standardized products may be transferred to peripheral branch plants or licensed when inter-corporate transfer occurs. This reduces the need for CNC systems in peripheral areas because the more standardized and mature nature of these products means that less sophisticated machinery may be installed for their production. This argument might also explain the greater use of unsophisticated handling systems in regions away from the Manufacturing Belt. In this context it is important to observe that CNC is not a normal piece of production hardware and its presence generally indicates that the adopter is involved in an area of manufacturing where product change and high quality is a basic requirement. These criteria are not synonymous with the archetypical branch plant more common in peripheral regions of a national economy.

## CONCLUSIONS

From this study of the spread of automated production technology in the American machinery industry we have seen that adoption rates do vary significantly by type of industry, by type of company, by size and age of plant and by the presence or absence of R and D. Our findings that older plants are more likely users of these new production technologies than newer plants is testimony to the continuous retooling process ongoing in the more established industrial areas of the country. This rejuvenation process has been glossed over by media accounts of American industrial change in recent times.

At its simplest, the study gives evidence that market mechanisms are working in the sense that such retooling is mandatory for firms to remain competitive. Since these adoption patterns also reveal regional differences (though not to a statistically significant degree), the study suggests a matching of capital with labor by region, i.e., the more advanced production technologies are being introduced in the higher skill, higher wage areas of the industrial Midwest while less of these technologies or less advanced versions are being introduced to a lesser degree in the lower wage, lower skill labor markets of the South and West. Indeed this alignment process can be seen to follow a product cycle interpretation of regional industrial change proposed earlier for the United States (Rees, 1979). The greater use of CNC in the industrial Midwest suggests at least for the machinery industry, that early development work is still on-going in that region, while more standardized production is still typical of peripheral regions in the South and West.

Other findings with policy implications are seen at the regional scale where small single-plant firms show significant differences in their propensity to adopt leading-edge technologies. Single-plant firms show far higher adoption rates for computerized machine control equipment in the industrial Midwest, the spawning-ground for the initial development of this technology. Likewise, the use of microprocessors in final products is more prevalent in their regions of origin: in this case the Northeast (notably Massachusetts) and the West (notably California). This suggests a contagious diffusion or distance-decay effect within regions that spawn leading-edge technologies, and is testimony to the propulsive nature of innovative regions. Though (as might be expected) multi-plant firms show much less regional variation in the adoption of the technologies under study, they are clearly more prevalent users of key technologies (computerized machine control and microprocessors) in metropolitan rather than nonmetropolitan environments. This again reflects the product cycle arguments at the metropolitan scale (Erickson and Leinbach, 1979). For policy-makers interested in the nurturing of small business in particular this study shows that small firms nearer to the source of innovation are more likely to use leading-edge technologies. Hence some attention may need to be given to encouraging the spread of these technologies to less innovating environments where multi-plant firms have a clear advantage over single-plant firms who suffer more from the tyranny of distance.

More detailed interviews with a sample of CNC adopters and non-adopters in two contrasting regions identified problems in acquiring skilled labor. It is suggested that such shortages in themselves may act as an incentive to adopt advanced process technologies like CNC. Because the introduction of advanced production systems in itself required retraining the existing labor force in a plant, this suggests that both industrialists and public policy-makers alike need to give high priority to labor training and retraining programs in future development strategies.

Table 1 POTENTIAL ADOPTERS BY INDUSTRY AND REGION

| SECTOR | N.E. | N.C. | S. | W. | US. |
|---|---|---|---|---|---|
| AGRI MACH | 24 | 411 | 164 | 96 | 695 |
| MACH TOOLS | 222 | 452 | 72 | 89 | 835 |
| CONSTR EQUIP | 53 | 211 | 108 | 56 | 428 |
| MECH HANDLING | 156 | 357 | 153 | 117 | 783 |
| ELEC MACHINERY | 234 | 354 | 177 | 125 | 890 |
| AIRCRAFT AND PARTS | 63 | 54 | 63 | 62 | 242 |
| TOTAL | 752 | 1839 | 737 | 545 | 3873 |

Data Source: Dun + Bradstreet
(plants > 20 empl.)

Table 2 RESPONDENTS BY CENSUS DIVISION

| | NEW ENG | MID ATL | ENC | WNC | SATL | ESC | WSC | MTN | PAC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL POP | 190 | 432 | 1135 | 460 | 238 | 149 | 236 | 65 | 352 | 3,257 |
| % | 5.8 | 13.3 | 34.9 | 14.1 | 7.3 | 4.6 | 7.3 | 2.0 | 10.8 | 100 |
| RESPONSES | 39 | 75 | 228 | 97 | 50 | 29 | 49 | 10 | 51 | 628 |
| % | 6.2 | 11.9 | 36.3 | 15.5 | 8.0 | 4.6 | 7.8 | 1.6 | 8.1 | 100 |

$\chi^2$ = 13.12, df. = 8, not significant at .05 level.

Table 3 RESPONDENTS BY METROPOLITAN CHARACTER
(Using Dept. of Agriculture Classification of US counties after Beale 1977)

| | CORE LARGE MET | FRINGE LARGE MET | MED METRO | SMALL METRO | ADJ CITY | NON ADJ CITY | ADJ TOWN | NOT ADJ TOWN | ADJ RURAL | NOT ADJ RURAL | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL POP | 985 | 418 | 674 | 247 | 213 | 156 | 238 | 258 | 19 | 49 | 3,257 |
| % | 30.2 | 12.8 | 20.7 | 7.6 | 6.5 | 4.8 | 7.3 | 7.9 | .6 | 1.5 | 100 |
| RESPONSES | 156 | 69 | 146 | 59 | 54 | 29 | 48 | 51 | 4 | 12 | 628 |
| % | 24.8 | 11.0 | 23.3 | 9.4 | 8.6 | 4.6 | 7.6 | 8.1 | .6 | 1.9 | 100 |

$\chi^2 = 13.43$, df = 9, not significant at .05 level.

Table 4 ADOPTION RATES BY INDUSTRIAL SECTOR

| | FARM MACH (352) | CONSTR MACH (353) | METAL WORK MACH (354) | ELEC DIST EQUIP (361) | ELEC IND APPAR (362) | AIR-CRAFT (392) | $\chi^2$ | PROB |
|---|---|---|---|---|---|---|---|---|
| NC | 20 | 43 | 58 | 23 | 36 | 68 | 65.5 | SIG .0001 |
| CNC | 23 | 37 | 58 | 27 | 44 | 70 | 54.6 | SIG .0001 |
| COMPUTER FOR COMMERCIAL | 63 | 69 | 61 | 67 | 62 | 82 | 6.9 | .228 |
| COMP FOR DESIGN | 10 | 21 | 19 | 36 | 28 | 51 | 36.6 | SIG .0001 |
| COMP FOR MFG | 34 | 49 | 46 | 41 | 40 | 55 | 8.7 | .122 |
| PROG HANDLING | 4 | 6 | 5 | 8 | 7 | 18 | 10.1 | .07 |
| NON-PROG HANDLING | 47 | 45 | 36 | 48 | 46 | 68 | 14.2 | SIG .014 |
| MICROPROC IN PRODUCT | 11 | 21 | 41 | 23 | 28 | 31 | 34.7 | SIG .0001 |
| TOTAL # of RESPONDENTS* | 132 | 170 | 152 | 77 | 57 | 40 | | |

*The number of respondents are not necessarily the same for each technique due to a limited number of missing values.

Table 5 ADOPTION RATES BY ORGAN STATUS

| | SPF | MPF | $\chi^2$ | PROB |
|---|---|---|---|---|
| NC | 25 | 56 | 58.8 | .0001 SIG |
| CNC | 31 | 51 | 26.0 | .0001 SIG |
| COMPUTER FOR COMMERCIAL | 54 | 78 | 37.3 | .0001 SIG |
| COMP FOR DESIGN | 11 | 34 | 39.4 | .0001 SIG |
| COMP FOR MFG | 29 | 57 | 44.2 | .0001 SIG |
| PROG HANDLING | 2 | 11 | 23.6 | .0001 SIG |
| NON-PROG HANDLING | 39 | 51 | 9.9 | .002 SIG |
| MICRO PROC IN PRODUCT | 19 | 33 | 15.4 | .0001 SIG |
| TOTAL # OF RESPONDENTS | 322 | 306 | | |

Table 6 ADOPTION RATES BY SIZE OF PLANT (EMPL.)

| | 1-19 | 20-99 | 100-249 | 250-999 | 1000 & MORE | $\chi^2$ | SIG |
|---|---|---|---|---|---|---|---|
| NC | 10 | 25 | 43 | 67 | 83 | 107.4 | .0001 SIG |
| CNC | 8 | 23 | 50 | 69 | 78 | 121.2 | .0001 SIG |
| COMPUTER FOR COMMERCIAL | 24 | 50 | 77 | 91 | 95 | 114.7 | .0001 SIG |
| COMP FOR DESIGN | 3 | 9 | 21 | 41 | 80 | 125 | .0001 SIG |
| COMP FOR MFG | 8 | 21 | 53 | 74 | 90 | 153.5 | .0001 SIG |
| PROG HANDLING | 0 | 1 | 2 | 15 | 35 | 88.1 | .0001 SIG |
| NON-PROG HANDLING | 48 | 43 | 39 | 51 | 60 | 8.2 | .083 |
| MICRO PROC IN PRODUCT | 5 | 19 | 32 | 36 | 40 | 29.2 | .0001 SIG |
| TOTAL # OF RESPONSES | 40 | 279 | 135 | 125 | 40 | | |

Table 7 ADOPTION RATES BY AGE OF PLANT

| | 1939 OR BEFORE | 1940 - 49 | 1950 - 59 | 1960 - 69 | 1970 - 81 | $\chi^2$ | SIG |
|---|---|---|---|---|---|---|---|
| NC | 59 | 52 | 41 | 33 | 28 | 32.7 | .0001 SIG |
| CNC | 57 | 46 | 45 | 37 | 27 | 26.0 | .0001 SIG |
| COMPUTER FOR COMMERCIAL | 79 | 70 | 67 | 62 | 58 | 13.3 | .009 SIG |
| COMP FOR DESIGN | 41 | 30 | 23 | 18 | 14 | 26.3 | .0001 SIG |
| COMP FOR MFG | 58 | 57 | 45 | 40 | 30 | 23.5 | .0001 SIG |
| PROG HANDLING | 9 | 16 | 6 | 5 | 2 | 16.3 | .003 SIG |
| NON-PROG HANDLING | 34 | 49 | 49 | 48 | 46 | 6.7 | .150 |
| MICRO PROC IN PRODUCT | 31 | 28 | 21 | 28 | 19 | 6.2 | .183 |
| TOTAL # OF RESPONDENTS | 111 | 63 | 109 | 181 | 150 | | |

Table 8 ADOPTION RATES BY R + D INTENSITY

| | NO R + D | R + D AT OTHER LOCATION | R + D ON SITE | $\chi^2$ | SIG |
|---|---|---|---|---|---|
| NC | 34 | 54 | 40 | 4.1 | .127 |
| CNC | 37 | 54 | 41 | 3.2 | .198 |
| COMPUTER FOR COMMERCIAL | 44 | 59 | 70 | 21.3 | .0001 SIG |
| COMP FOR DESIGN | 14 | 23 | 24 | 4.1 | .130 |
| COMP FOR MFG | 23 | 59 | 46 | 16.4 | .0003 SIG |
| PROG HANDLING | 4.6 | 14 | 6 | 3.8 | .153 |
| NON-PROG HANDLING | 45 | 50 | 45 | .4 | .818 |
| MICRO PROC IN PRODUCT | 15 | 12 | 28 | 9.8 | .008 SIG |
| TOTAL # OF RESPONDENTS | 87 | 36 | 505 | | |

Table 9 ADOPTION RATES BY CENSUS REGION

| | NE | NC | S | W | $\chi^2$ | PROB |
|---|---|---|---|---|---|---|
| NC | 39 | 45 | 32 | 35 | 7.68 | .053 |
| CNC | 41 | 47 | 28 | 37 | 12.4 | .006 SIG |
| COMPUTER FOR COMMERCIAL | 62 | 69 | 63 | 62 | 2.7 | .441 |
| COMP FOR DESIGN | 23 | 22 | 23 | 25 | .2 | .977 |
| COMP FOR MFG | 47 | 46 | 38 | 36 | 3.9 | .272 |
| PROG HANDLING | 6 | 7 | 4 | 11 | 3.9 | .267 |
| NON-PROG HANDLING | 40 | 42 | 55 | 51 | 8.4 | .038 SIG |
| MIC PROC IN PRODUCT | 31 | 26 | 20 | 23 | 4.3 | .226 |
| TOTAL # OF RESPONDENTS | 114 | 325 | 128 | 61 | | |
| AVERAGE RANK (EXCL NON-PROG HANDLING) | 2 | 1.9 | 3.3 | 2.6 | | |

Table 10 ADOPTION RATES BY METROPOLITAN LOCATION

| | LARGE METRO | SMALL METRO | URBAN | RURAL | $\chi^2$ | PROB |
|---|---|---|---|---|---|---|
| NC | 43 | 46 | 36 | 30 | 8.7 | .03 SIG |
| CNC | 43 | 42 | 41 | 33 | 3.06 | .383 |
| COMPUTER FOR COMMERCIAL | 62 | 66 | 74 | 62 | 6.07 | .108 |
| COMP. FOR DESIGN | 26 | 20 | 25 | 19 | 2.4 | .492 |
| COMP FOR MFG | 46 | 39 | 49 | 40 | 3.95 | .267 |
| PROG HANDLING | 7 | 6 | 7 | 4 | 1.18 | .759 |
| NON-PROG HANDLING | 44 | 43 | 48 | 46 | .879 | .831 |
| MICRO PROC IN PRODUCT | 28 | 33 | 17 | 18 | 12.2 | .007 SIG |
| TOTAL # OF RESPONDENTS | 218 | 175 | 140 | 95 | | |
| AVERAGE RANK (EXC NON-PROG HANDLING) | 1.7 | 2.3 | 2.1 | 3.6 | | |

Table 11 REGIONAL ADOPTION RATES BY SECTOR: CONSTRUCTION MACHINERY

| | NE | NC | S | W | PROB. |
|---|---|---|---|---|---|
| NC | 31 | 49 | 38 | 40 | .33 |
| CNC | 28 | 46 | 28 | 33 | .17 |
| COMPUTER FOR COMMERCIAL | 68 | 65 | 73 | 79 | .69 |
| COMP FOR DESIGN | 8 | 29 | 15 | 17 | .10 |
| COMP FOR MFG | 38 | 53 | 47 | 46 | .61 |
| PROG HANDLING | 7 | 7 | 0 | 20 | .06 |
| NON-PROG HANDLING | 52 | 40 | 52 | 33 | .40 |
| MICROPROC IN PRODUCT | 32 | 25 | 21 | 23 | .28 |
| TOTAL # OF RESPONDENTS | 29 | 84 | 42 | 15 | |

Table 12 REGIONAL ADOPTION RATES BY ORGANIZATIONAL STATUS

| | | NE | NC | S | W | PROB |
|---|---|---|---|---|---|---|
| NC | SPF | 27 | 31 | 11 | 17 | .02* |
| | MPF | 55 | 60 | 49 | 53 | .47 |
| CNC | SPF | 37 | 37 | 16 | 13 | .004* |
| | MPF | 47 | 56 | 38 | 60 | .06 |
| COMPUTER FOR COMMERCIAL | SPF | 54 | 58 | 47 | 43 | .36 |
| | MPF | 70 | 80 | 76 | 80 | .52 |
| COMP FOR DESIGN | SPF | 17 | 9 | 10 | 15 | .49 |
| | MPF | 31 | 36 | 32 | 34 | .93 |
| COMP FOR MFG | SPF | 38 | 32 | 20 | 15 | .07 |
| | MPF | 57 | 60 | 52 | 55 | .76 |
| PROG HANDLING | SPF | 3 | 2 | 0 | 3 | .37** |
| | MPF | 10 | 12 | 7 | 19 | .35 |
| NON-PROG HANDLING | SPF | 37 | 35 | 47 | 47 | .30 |
| | MPF | 43 | 49 | 61 | 55 | .22 |
| MICROPROC IN PRODUCT | SPF | 33 | 16 | 11 | 20 | .01* |
| | MPF | 29 | 38 | 27 | 27 | .33 |

*Statistically significant (using chi square).
**More than 20 percent of cells have expected counts less than 5.

Table 13 METROPOLITAN ADOPTION RATES BY ORGANIZATIONAL STATUS

| | | LARGE METRO | SMALL METRO | URBAN | RURAL | PROB |
|---|---|---|---|---|---|---|
| NC | SPF | 27 | 29 | 22 | 19 | .56 |
| | MPF | 62 | 62 | 49 | 40 | .03* |
| CNC | SPF | 32 | 32 | 36 | 19 | .27 |
| | MPF | 56 | 52 | 46 | 47 | .58 |
| COMPUTER FOR COMMERCIAL | SPF | 51 | 53 | 65 | 45 | .15 |
| | MPF | 74 | 79 | 83 | 77 | .56 |
| COMP FOR DESIGN | SPF | 12 | 9 | 13 | 12 | .83 |
| | MPF | 39 | 31 | 36 | 26 | .47 |
| COMP FOR MFG | SPF | 32 | 27 | 36 | 17 | .17 |
| | MPF | 59 | 49 | 62 | 62 | .39 |
| PROG HANDLING | SPF | 1 | 4 | 3 | 0 | .36** |
| | MPF | 15 | 9 | 12 | 9 | .54 |
| NON-PROG HANDLING | SPF | 38 | 39 | 40 | 40 | .99 |
| | MPF | 51 | 48 | 56 | 53 | .77 |
| MICROPROC IN PRODUCT | SPF | 17 | 29 | 12 | 15 | .04* |
| | MPF | 41 | 36 | 23 | 22 | .04* |

*Statistically significant (using chi square test).
**More than 20 percent of cells have expected counts less than 5.

Table 14 REGIONAL ADOPTION RATES BY EMPL. SIZE OF PLANT

| | | NE | NC | S | W | PROB. |
|---|---|---|---|---|---|---|
| NC | 1-99 | 27 | 25 | 16 | 19 | .43 |
| | ≥100 | 54 | 63 | 50 | 54 | .27 |
| CNC | 1-99 | 29 | 24 | 9 | 16 | .02 |
| | ≥100 | 56 | 67 | 52 | 62 | .16 |
| COMPUTER FOR COMMERICAL | 1-99 | 46 | 48 | 46 | 39 | .83 |
| | ≥100 | 79 | 87 | 85 | 89 | .59 |
| COMP FOR DESIGN | 1-99 | 13 | 7 | 7 | 10 | .57 |
| | ≥100 | 37 | 35 | 43 | 46 | .66 |
| COMP FOR MFG | 1-99 | 24 | 21 | 16 | 7 | .25 |
| | ≥100 | 69 | 68 | 65 | 68 | .97 |
| PROG HANDLING | 1-99 | 2 | 1 | 0 | 3 | .59 |
| | ≥100 | 11 | 12 | 9 | 19 | .65 |
| NON-PROG HANDLING | 1-99 | 40 | 40 | 54 | 47 | .21 |
| | ≥100 | 39 | 44 | 55 | 59 | .16 |
| MICROPROC IN PRODUCT | 1-99 | 21 | 17 | 10 | 23 | .30 |
| | ≥100 | 42 | 35 | 31 | 26 | .48 |

Table 15 REGIONAL ADOPTION RATES BY AGE OF PLANT

| | | NE | NC | S | W | PROB |
|---|---|---|---|---|---|---|
| NC | pre 1960 | 40 | 60 | 36 | 41 | .005 |
| | 1960 or later | 39 | 29 | 29 | 29 | .51 |
| CNC | pre 1960 | 43 | 60 | 29 | 41 | .001 |
| | 1960 or later | 39 | 32 | 28 | 35 | .52 |
| COMPUTER FOR COMMERCIAL | pre 1960 | 71 | 77 | 67 | 54 | .08 |
| | 1960 or later | 53 | 61 | 61 | 66 | .65 |
| COMP FOR DESIGN | pre 1960 | 26 | 32 | 36 | 30 | .84 |
| | 1960 or later | 20 | 13 | 16 | 23 | .40 |
| COMP FOR MFG | pre 1960 | 56 | 58 | 42 | 33 | .08 |
| | 1960 or later | 38 | 34 | 36 | 37 | .95 |
| PROG HANDLING | pre 1960 | 7 | 11 | 5 | 15 | .48 |
| | 1960 or later | 5 | 3 | 4 | 6 | .66 |
| NON-PROG HANDLING | pre 1960 | 37 | 39 | 57 | 59 | .04 |
| | 1960 or later | 42 | 46 | 53 | 44 | .58 |
| MICROPROC IN PRODUCT | pre 1960 | 27 | 29 | 23 | 12 | .26 |
| | 1960 or later | 33 | 22 | 18 | 31 | .17 |

Table 16 METROPOLITAN ADOPTION RATES BY AGE OF PLANT

| | | LARGE METRO | SMALL METRO | URBAN | RURAL | PROB. |
|---|---|---|---|---|---|---|
| NC | pre 1960 | 51 | 51 | 55 | 37 | .99 |
| | post 1960 | 35 | 40 | 16 | 27 | .009* |
| CNC | pre 1960 | 51 | 50 | 48 | 50 | .99 |
| | post 1960 | 35 | 34 | 32 | 25 | .59 |
| COMPUTER FOR COMMERCIAL | pre 1960 | 66 | 72 | 76 | 85 | .24 |
| | post 1960 | 57 | 59 | 71 | 53 | .17 |
| COMP FOR DESIGN | pre 1960 | 35 | 26 | 38 | 19 | .25 |
| | post 1960 | 17 | 14 | 13 | 19 | .75 |
| COMP FOR MFG | pre 1960 | 56 | 44 | 60 | 48 | .24 |
| | post 1960 | 35 | 33 | 38 | 37 | .94 |
| PROG HANDLING | pre 1960 | 14 | 6 | 10 | 3 | .21 |
| | post 1960 | 1 | 6 | 4 | 5 | .28** |
| NON-PROG HANDLING | pre 1960 | 46 | 42 | 45 | 33 | .67 |
| | post 1960 | 42 | 45 | 51 | 53 | .48 |
| MICROPROC IN PRODUCT | pre 1960 | 30 | 27 | 20 | 28 | .59 |
| | post 1960 | 26 | 36 | 15 | 15 | .007* |

*Statistically significant (using chi square).
** More than 20 percent of cells have expected counts less than 5.

Table 17 DIFFICULTY IN RECRUITING SKILLED WORKERS

N = 37

| | ADOPTERS | | NON-ADOPTERS | |
|---|---|---|---|---|
| | ENC | WSC | ENC | WSC |
| YES | 5 | 3 | 7 | 4 |
| NO | 4 | 4 | 2 | 8 |
| Total | 9 | 7 | 9 | 12 |

Table 18 RETRAINING UNDERTAKEN

N = 37

| | ADOPTERS | | NON-ADOPTERS | |
|---|---|---|---|---|
| | ENC | WSC | ENC | WSC |
| YES | 8 | 5 | 1 | 3 |
| NO | 1 | 2 | 8 | 9 |
| Total | 9 | 7 | 9 | 12 |

Table 19 ASSEMBLY LINE PRODUCTION PRACTICED

N = 37

| | ADOPTERS | | NON-ADOPTERS | |
|---|---|---|---|---|
| | ENC | WSC | ENC | WSC |
| YES | 1 | 4 | 6 | 6 |
| NO | 8 | 3 | 3 | 6 |
| Total | 9 | 7 | 9 | 12 |

Table 20 USE OF NC

| N = 37 | ADOPTERS | | NON-ADOPTERS | |
|---|---|---|---|---|
| | ENC | WSC | ENC | WSC |
| YES | 8 | 3 | 5 | 2 |
| NO | 1 | 4 | 4 | 10 |
| Total | 9 | 7 | 9 | 12 |

Table 21 FUTURE CNC ADOPTION

| N = 35 | ADOPTERS | | NON-ADOPTERS | |
|---|---|---|---|---|
| | ENC | WSC | ENC | WSC |
| YES | 7 | 4 | 5 | 2 |
| NO | 2 | 3 | 3 | 9 |
| Total | 9 | 7 | 8 | 11 |

## REFERENCES

Armington, C. and M. Odle (1982), Small business - how many jobs? Brookings Review, pp. 14-17.

Beale, C.L. (1977), The recent shift of U.S. population to nonmetropolitan areas 1970-75, International Regional Science Review, 2, pp. 113-122.

Dorfman, N.A. (1982), Massachusetts' High Technology Boom in Perspective, Center for Policy Alternatives (Discussion Paper), M.I.T.

Erickson, R.A. and T.R. Leinbach (1979), Characteristics of branch plants attracted to nonmetro areas, in R. Lonsdale and H. Seyler, Nonmetropolitan Industrialization, Washington, D.C.: Winston, pp. 57-78.

Ewers, H.J. and R.W. Wettman (1980), Innovation-Oriented Regional Policy, Regional Studies, 14, pp. 161-180.

Hansen, N. (1980), The New International Division of Labor and Manufacturing Decentralisation in the United States, Review of Regional Studies, 9, pp. 1-11.

National Research Council (1981), Innovation and Transfer of U.S. Airforce Manufacturing Technology, Washington, D.C.: National Academy Press.

Nelson, R. and S. Winter (1977), In Search of a Useful Theory of Innovation, Research Policy, 6, pp. 36-76.

Oakey, R., A. Thwaites and P. Nash (1980), The Regional Distribution of Innovative Manufacturing Establishments in Britain, Regional Studies, 14, pp. 235-254.

Premus, R. (1982), Staff study for Joint Economic Committee (1982), Location of High Technology Firms and Regional Economic Development, Washington, D.C.: USGPO.

Rees, J. (1979), Technological change and regional shifts in American Manufacturing, Prof. Geog., 31, pp. 45-54.

Rosenberg, N. (1972), Technology and American Economic Growth, New York: Harper and Row.

Thwaites, A. (1978), Technological change, Mobile Plants, and Regional Development, Regional Studies, 12, pp. 445-461.

Utterback, J.M. (1979), The Dynamics of Product and Process Innovation in Industry, in C. Hill and J. Utterback (eds.), Technological Innovation for a Dynamic Economy, New York: Pergamon.