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INTERSTATE VARIATIONS IN MANUFACTURING GROWTH IN THE U.S.: DUAL ROLES OF TECHNOLOGICAL CHANGE

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INTERSTATE VARIATIONS IN MANUFACTURING GROWTH IN THE U.S.:

DUAL ROLES OF TECHNOLOGICAL CHANGE

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ABSTRACT

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The study of technological change and regional economic growth has traditionally been concerned with process technology only. As an alternative to this approach, the concept of dual roles of technological change has recently been suggested in order to emphasize the importance of product technology and its effect on process technology for long-term regional economic growth.

This study tests an hypothesis that interstate variations in the growth rate of manufacturing output in the United States are determined by the combined rates of change in state process and product technologies. In addition, this study examines 1) the individual relationships between the growth rate of state manufacturing output and the rates of change in state process and product technologies, 2) the regional variations in the rates of change in state process and product technologies, and 3) the regional patterns in state patenting activity and its intensity.

The results of this study confirm the hypothesis for the variables

and the time periods selected for the test. In explaining the interstate variations in the growth rate of state manufacturing output, the rate of change in high and intermediate state product technology was found to be more important than the rate of change in low state product technology or in state process technology. The results also indicate shifting core-periphery relationships in the rates of change in state process and product technologies and in state patenting activity and its intensity, and the importance of research and development activities for state patenting activity and its intensity.

CHAPTER I

INTRODUCTION

The role of technological change has not been clearly identified in research on technological change and regional economic growth, despite a widespread recognition of the importance of technological change for regional economic growth in recent years. This is attributable to the complex nature of the concept of technological change itself (Kennedy and Thirlwall, 1972), and also to the failure to identify the process through which technological change influences regional economic growth (Thomas, 1975).

Much of the research on technological change is characterized by an attempt to identify the nature of technological change. However, it has been concerned mainly with individual elements of technological change rather than with the relationships among these elements and with the relationship between technological change and regional growth. Hence it has focused on identifying the factors affecting such elements as research and development (R&D), patenting, innovation, and innovation diffusion. The studies on these individual elements of technological change and their empirical findings are reviewed in Chapter II.

Until recently, technological change had not been the focus of research on regional economic growth. Neoclassical regional growth models based on the notion of interregional growth convergence assumed technological change as merely one of many factors which freely flow among regions. The obvious difficulties in explaining interregional growth disparities with the neoclassical models led to the development of unbalanced interregional growth models, such as cumulative causation, growth poles, and core-periphery approaches. However, these models have been concerned primarily with short-term quantitative effects rather than long-term qualitative effects of technological change on regional economic growth.[1]

The search for an alternative approach to the study of the role of technological change in regional economic growth has recently produced the concept of dual roles of technological change. Thomas (1975) has suggested that long-term growth of a region is determined not only by productivity improvement resulting from the change in process technology, which has only a short-term quantitative effect on regional economic structure, but also by the new products created by the change in product technology of the region which have a long-term effect on regional economic structure. In short, Thomas attributed long-term interregional growth disparities to the dual effects of technological change on regional manufacturing output growth and on the change in regional economic structure. This concept of dual roles of technological change as well as neoclassical regional growth models and unbalanced interregional growth models are examined in Chapter III.

The principal goal of this study is to test an hypothesis establish-

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[1]Growth pole theory (Perroux, 1955), as one type of unbalanced interregional growth model, is concerned with a short-term quantitative change in the level of outputs of an economic system technologically linked to a "propulsive industry" rather than with a long-term structural change in interfirm or interindustry input-output linkages (Thomas, 1975, p.7).

ed on the basis of the concept of dual roles of technological change--that interstate variations in the growth rate of state manufacturing output in the United States are determined by the rates of change in state process and product technologies. In addition, this study examines the individual relationships between the growth rate of state manufacturing output and the rates of change in state process technology and in state product technology which have never been tested in the studies on technological change and regional economic growth.[2]

The hypothesis is tested with five specific variables employed in two sets of models. They include 1) the rate of change in the state total of value-added for the growth rate of state manufacturing output, 2) the rates of change in state total factor productivity and in the estimated number of patents utilized as process technology, both representing the rate of change in state process technology, and 3) the rates of change in the estimated number of patents produced by high and intermediate technology industries and by low technology industries for the use as product technology, both representing the rate of change in state product technology.

Of the four variables representing technological change, the rate of change in total factor productivity is the only measure that has been used by economists. The other three variables, measuring state process and product technologies, are the measures devised exclusively for this study on the basis of Scherer's (1982b) findings on R&D utilization by industry in

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[2]The only study on the relationship between the growth rate of state manufacturing output and technological change that has been performed so far is Casetti's (1982) analysis of the relationships between labor productivity growth and the growth of population and manufacturing output at the state level.

his study of interindustry technology flows in the United States.[3] A detailed discussion on the selection of these variables, the data for these variables, and the methods of testing the hypothesis are provided in Chapter V.

Due to the lack of data on patent utilization, past research on patenting has focused on explaining patenting as a distinctive economic activity with its economic determinants, rather than on the use of patents as a measure of technology. In addition, the research has been concerned with patenting activity at city, national, and even international levels (Pred, 1966; Schmookler, 1966; Pavitt and Soete, 1980), but rarely at the state level. With new state patent date which has become available since 1977, this study analyzes the regional patterns in the distribution of state patenting activity and explains them with R&D measures in Chapter IV.

Regional patterns in the distribution of each of the four variables measuring the rates of change in state process and product technologies are also analyzed in order to examine the shifting core-periphery relationships in the United States in each variable. The previous empirical studies have been concerned with the interregional shifts in manufacturing employment (Norton and Rees, 1979; Rees, 1979). The regional patterns in the distribution of the four variables as analyzed in Chapter VI provide additional dimensions to the study of the shifting core-periphery relationships in the United States.

The hypothesis is confirmed by the results of multiple regression analyses of the growth rate of state manufacturing output on the rates of

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[3]Scherer's study (1982b) is a breakthrough in the research on patenting and R&D activities in the sense that the study makes it possible to quantify technological change with R&D expenditures.

change in state process technology and in state product technology. However, the evidence presented by the regression analyses is consistent with the hypothesis for the periods selected in this study within the limitations of data availability. Also, the relative importance among each of the four independent variables and between each of the two sets of the variables is determined by the regression analyses of individual relationships between the growth rate of state manufacturing output and these variables. All results of these analyses are presented in Chapter VI.

Finally, this study is concluded in Chapter VII by summarizing significant findings, and identifying the contributions of this study to the research on technological change and regional growth. In addition, proposals are made for further research to be undertaken in order to fully test the concept of dual roles of technological change in regional economic growth.

CHAPTER II

THE CONCEPT OF TECHNOLOGICAL CHANGE

Technological change is too elusive and complex a concept to be unequivocally defined or quantified.[1] Consequently, it is useful to identify the sources of technology and the process through which technology evolves, and to measure technological change by its economic effects. For this purpose, this chapter reviews the studies on major elements of technological change including research and development (R&D), patenting, innovation, innovation diffusion, and productivity and attempts to determine the relationships among these elements in the complex process of technological change

The Process of Technological Change

Technological change may be defined in a number of different ways, but generally, it is accepted as the change in the state of human knowledge as applied in production (Rosegger, 1980; Mansfield, 1968; Schmookler, 1066). The process through which the state of productive human knowledge (technology) changes is complex, but usually it has been divided into two

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[1]This chapter provides only a very selective review of the technological change literature. For more comprehensive accounts, see Freeman, 1982; Mansfield, 1968; Mansfield et al., 1971; Rosegger, 1980; and Schmookler, 1966.

major stages including R&D and diffusion, as shown in Figure 1.

Research and development (R&D) encompasses work of many different kinds, but it is viewed essentially as the set of activities leading up to the first production of new products or to the first application of new processes to production (Rosegger, 1980). Traditionally, R&D has been identified with three phases of research activities including basic research, applied research, and development.[2] Basic research is concerned with the increase in scientific knowledge, which together with the existing pool of inventions and technical information forms the basis, on which applied research is conducted. Because the output of this phase is not productive, this phase of R&D has no direct effect on technological change (Rosegger, 1980). A large portion of basic research is done in universities and research institutes, outside of the conventional corporate R&D.

Applied research is the activity leading to inventions, which represent the beginning of technological change. A relatively small portion of inventions are usually patented for legal protection and/or selected for development. Development activity produces three different types of innovations including new processes, new products, and product improvements (Thomas, 1975; Malecki, 1983b). Much R&D effort, however, is oriented toward product improvement and incremental changes in existing production processes (Rosenberg, J., 1976).

The diffusion stage begins with the adoption of an innovation by initial adopters. The innovation diffuses geographically and among adopters,

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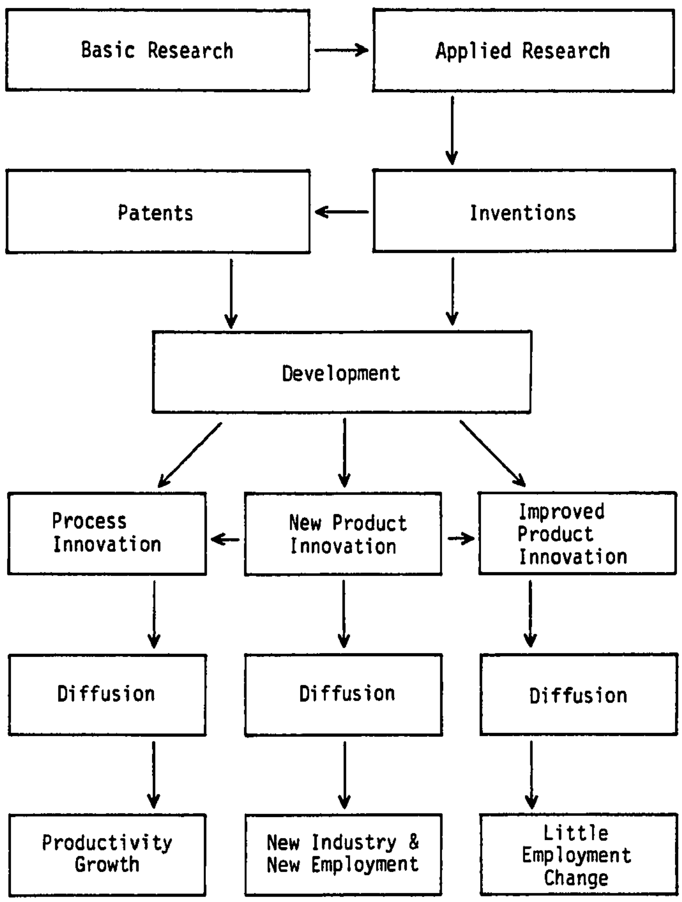
[2]For exhaustive definitions of basic research, applied research, and development, see National Science Board, Science Indicators, 1974 (Washington, D.C.: U.S. Government Printing Office, 1975).

FIGURE 1

STAGE MODEL OF TECHNOLOGICAL CHANGE



Source: Adapted from G. Rosegger, The Economics of Production and Innovation: An Industrial Perspective (New York: Pergamon Press, 1980), p. 8.; E. J. Malecki, Towards A Model of Technical Change and Regional Economic Change, Regional Science Perspectives, 13 (1983b).

who may be individuals or firms. After the earliest adoptions, other potential adopters adopt the innovation based on the information provided by the initial adopters concerning the advantages and problems associated with using the innovation (Rosegger, 1980). Adjustments are usually made to the innovation as minor problems are found during this stage. It is the diffusion of an innovation throughout industry that has the most noticeable effect on an economy (Nelson, 1981). Hence, major innovations and those that diffuse rapidly will have the greatest economic impact.[3]

Technological change as described above is not an automatic process. Innovation and commercialization (diffusion) of individual products depend considerably on corporate decisions which must be made based on corporate strategies in a cyclical and recursive manner throughout the process of technological change (Rosegger, 1980). Anywhere along the process, they will be terminated or slowed down depending on market conditions, investment requirements, and technical problems (Rosegger, 1980).

Research and Development

Research on R&D has been oriented toward identifying the economic nature of R&D activities with its focus on 1) the relationships between R&D intensity and the factors affecting it, and 2) the return on R&D investment. R&D intensity has been measured typically by R&D expenditures as a percentage of sales and is considered to be a function of market structure (as measured by a firm's market share) or firm size. Empirical studies on

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[3]Major innovations are those innovations which "clearly generate major discontinuities in industries and markets", and stimulate a wide range of incremental innovations (Rosegger, 1980, p. 15).

R&D intensity suggest generally a negative relationship between R&D intensity and a firm's market share (Comanor, 1967; Scherer, 1967; Rosenberg, J., 1976) and a non-linear relationship between R&D intensity and firm size (Scherer, 1965; Mansfield, 1968).

Return on R&D investment has been analyzed usually in terms of the relationship between R&D input and output. Studies show either a strong correlation between R&D input as measured by R&D personnel or expenditures and output as measured by patents, significant inventions, or innovations (Mansfield, 1968; Comanor and Scherer, 1969) or no conclusive evidence of significant return to R&D investment (Kochanowski and Hertzfeld, 1981).

The studies discussed above represent a typical neoclassical approach which treats R&D investment as subject to the same profit-maximizing principle as other investment, and ignores the effects of multiple R&D performers, learning-by-doing, and imitation (Nelson, 1981). Moreover, a high level of aggregation in R&D data obscures the characteristics of individual firms and industries (Gold, 1977). More serious, however, is that the studies on R&D returns attribute the changes in R&D output solely to the changes in the level of R&D input, excluding other internal or external factors related to a firm's operations such as procurement, production and marketing, and a firm's competitive advantage over its competitors (Gold, 1977).

Dissatisfied with this neoclassical approach as used in the analysis of the economic nature of R&D, some researchers have focused their attention on organizational behavior in R&D activities. Examples of this approach include studies on product R&D (Abernathy and Utterback, 1978), corporate strategies on R&D (Thomas, 1981; Gold, 1980; Freeman, 1974), R&D organization (Thomas and Le Heron, 1975; Malecki, 1980b) and firm responses to uncertainty in market conditions, technological competitiveness and buyer behavior (Rosenberg, N., 1976; Nelson, 1981; Thomas and Le Heron, 1975). None of these perspectives has yet replaced the neoclassical approach described above, but together this recent research furnishes additional realism to the traditional models.

Patenting and Patent Utilization

Patenting has traditionally been studied in relation to R&D activities because many researchers of technological change have viewed it as an economic activity resulting from R&D. Consequently, the research on patenting has focused on identifying the economic nature of patenting, on employing patents as a measure of R&D, and on estimating patent utilization by industries.

Patenting As an Economic Activity

The unique nature of patenting activity as a means of protecting inventions and as a part of R&D activities has led some researchers to study patenting as an economic activity. Consequently, they were concerned primarily with economic determinants of patenting activity. Schmookler (1966) was the first to identify the supply and demand factors of patents.[4] He

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[4] A patent is defined in the American legal system by the Patent Act of 1952 as "the right to exclude others from making, using, or selling the invention". In order to be patentable, an invention must be 1) new and undubious, 2) not previously achieved, 3) useful and important, and 4) not injurious to public morals and health (Rosegger, 1980). In addition, patents may be granted on "any new and useful improvement thereof" or "certain designs and new strains of botanical plants" (Rosegger, 1980, p. 169). Patents used to be the monopoly of individual inventors. However, with the growth of organized corporate R&D activities, most patents are now produced by corporate researchers and they are the property of the firms involved.

developed a model where the supply of inventions was determined by the number of creative individuals and the state of knowledge, and the demand for inventions was determined by economic conditions, especially the demand for investment goods and expected profitability.

Schmookler (1966) emphasized inventive activity as an endogenous phenomenon with demand the principal component. Recently, Rosegger (1980) also emphasized the importance of demand factors in inventive activity by arguing that the rate at which inventions are produced is determined entirely by the expected return to inventors (whether individuals or their corporate counterparts).

Schmookler's demand-pull hypothesis has been reevaluated recently. For example, Stoneman (1979), after investigating the cost of producing inventions in the U.K., suggested that Schmookler's hypothesis be modified to one where both demand (e.g., market size and diffusion speed) and cost factors (e.g., R&D expenditures per patent) determine the level of patenting activity. Scherer tested Schmookler's hypothesis with a new and comprehensive data set. In a series of regression analyses, he could find generally strong correlations only between capital goods (process) patenting and industry investment. He concluded that Schmookler's theory does not survive, "when all manufacturing industry rather than a small subset is investigated and when materials (products) inventions are the focus" (Scherer, 1982a, p. 236).

Patents As a Measure of R&D

Patents have been used as a popular measure of R&D activities, primarily due to the lack of satisfactory R&D measures. Typical R&D measures such as expenditures (Mansfield, 1968), the number of R&D employees (Scherer, 1967; Malecki, 1980c), the number of significant innovations (Mansfield, 1968), the sales of new products (Comanor, 1965), and R&D intensity (i.e., R&D expenditures as a percentage of sales) (Malecki, 1980a) capture only certain aspects of R&D rather than the overall performance of R&D activities. In addition, appropriate data on R&D often are not readily available. When they are available, however, they are likely to be incomplete either in time series or by spatial unit.

The principal advantage of patents over other R&D measures is simply the availability of patent data. Data on U.S. patents aggregated by state are available annually from 1883 to 1980 (U.S. Patent and Trademark Office, 1977; 1982). This advantage, together with a close empirical correlation between patents and R&D employees, has made patents a traditionally preferred measure of R&D input (Mansfield, 1968) and output in studies concerning technological change (Schmookler, 1966; Scherer, 1965). Patents may also be transformed into other meaningful measures such as propensity to patent (i.e., the number of patents per R&D expenditure) (Taylor and Silberston, 1973) and per capita patents (Pavitt and Soete, 1980; Pavitt, 1982), in order to measure R&D output and innovative activities, respectively.

However, patents have never been used as a measure of the entire process (input and output) of technological change, although they have been frequently referred to as a crude indicator of technological change. Schmookler (1966) explored the possibility of using patents as a direct measure of technological change by testing the relationship between the patent growth rate and the productivity growth rate. The result was disappointing and he attributed it to the tendency of patenting activity of successive years to yield smaller and smaller increases in productivity.

The use of patents as a measure of R&D ignores some inherent problems in patenting activity. First, in the process of technological change, patents represent a portion of inventions produced by applied research, which is two steps away from the first production phase, innovation. Theoretically, patents do not represent innovations, although they have been frequently used as a measure of innovations (Pavitt and Soete, 1980; Freeman, 1982). Second, the sheer number of patents is meaningless in measuring the economic effect of R&D, because a large portion of patents usually remains dormant without ever being developed and commercialized (Rosegger, 1980). Third, from a geographical perspective, patent data do not show the location of either where the patented knowledge is developed or where it is applied to production. In addition, the location of a patent holder is likely to be different from that of plants which utilize innovations originating from patented inventions (Feller, 1975). This prevents the use of patent data in a spatial analysis of technology flow.

Patent Utilization

Patent utilization is probably the single most important subject to be studied for the progress of research on R&D and technological change in general, because it is the innovations resulting from patented inventions which really contribute to technological change as well as economic growth. However, little research has been done on this subject, primarily due to the enormous amount of work required to collect and classify patent data, to trace the interindustry flow of patented technology, and to estimate the contributions of patented inventions to the outputs of user industries. Sanders (1958) was one of the first to study commercial utilization of patents. Sanders' (1964) analysis of utilization status of some 600 randomly sampled patents granted in 1938, 1948, and 1952 shows an average of over 50 percent utilization rate of patents assigned to industries, and the average patent utilization rate of small firms higher than that of larger firms.[5]

Subsequent research, however, has been concerned primarily with identifying the differences among selected manufacturing industries in patent utilization. For example, Mansfield (1968, p. 209) found that the electronics, chemicals, and drug industries make extensive use of their patents, while the automobile, paper, and rubber industries do not. These early studies, however, tended to ignore the possibility of innovations originating in one industry being used in or even primarily benefitting another industry.

Most recently, Scherer (1982b) completed probably the most important and comprehensive study on R&D utilization. He developed a detailed interindustry technology flow matrix, which shows the input-output relationship among industries in R&D as measured by 1974 R&D expenditures.[6] Scherer's matrix provides answers to some important questions on technological change such as patent and R&D utilization, interindustry dependency in product and process R&D, and the productivity of R&D for individual industries. In particular, it helps to furnish much needed data about the product innovations

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[5]Taylor and Silberston (1973, pp. 46-49) attributed Sanders' findings of the high average patent utilization rate of assigned industries to a sampling error resulting from excluding "lapsed" patents from his analysis.

[6]Scherer's interindustry technology flow matrix was developed on the basis of his survey of 1974 R&D outlays of 443 corporations, some 15,000 patents issued to these corporations in 1976 and 1977, and 1972 sales of "originating" industries, and also on the basis of his estimation of 1972 sales of "potential user" industries (Scherer, 1982b, pp. 232-241).

of some industries that become the process innovations used in other industries. In addition, Scherer's matrix provides a basis for estimating patent utilization for individual industries or a group of industries.

Innovation and Diffusion

Innovation, which follows R&D in the process of technological change, represents the beginning of some noticeable change in the level of technology as well as the first commercial application of inventions selected at the end of R&D stage. However, it is the diffusion of innovations that more directly affects the measured technological change and economic growth.

Innovation

Innovation is not just a process of the first commercial application of a small portion of inventions produced in the R&D stage, but a whole process of applying inventions to production, of modifying and adjusting new products and processes, and of improving existing products.[7] Research on innovation has focused on corporate strategies on innovation, the relationship between innovation and R&D, and the innovation process.

Studies on innovation strategies have been concerned with identifying the types of strategies firms use in introducing and marketing new products (Freeman, 1982, pp. 169-186; Krumme and Hayter, 1975). The relationship between innovation and R&D and the innovation process have been

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[7]A distinction must be made between "an innovation" and "innovation". An innovation is usually defined as an invention which is commercially applied for the first time (Mansfield, 1968, p. 99), while innovation is viewed as an action taken for commercial utilization of an innovation (Schmookler, 1966, p. 2). Therefore, an innovation, whether it is a new product, new process or improved product, may be regarded as the result of innovative activity (innovation).

studied within the general framework of the product life cycle or innovation cycle concept, which conveniently relates innovation to R&D at each stage of the innovation process (Malecki, 1981; Abernathy and Utterback, 1978).[8] In addition, some R&D studies examined the relationship between innovation and R&D indirectly by using innovations as a measure of R&D output as reviewed previously in this chapter (Mansfield, 1968; Comanor and Scherer, 1969).

Innovation Diffusion

Most research on innovation diffusion has been focused on spatial diffusion of innovations, the rates of diffusion for particular innovations, and the factors affecting the differences in such rates. Research on diffusion rates has focused on identifying interindustry and interfirm differences in diffusion rates typically by using an epidemic model (Thomas and Le Heron, 1975; Davies, 1979). Traditionally, the differences in diffusion rates in general have been explained in terms of expected cost savings or profitability (Kennedy and Thirlwall, 1972). Recently, however, they have been related to a number of other factors such as competitive market pressure (Parker, 1974; Gold, 1980), risk and uncertainty (Rosenberg, N., 1976; Nelson, 1981), access to capital (Thomas and Le Heron, 1975), information channels (Kennedy and Thirlwall, 1972; Rosegger, 1980), and institutional factors such as patents (Nelson, 1981).

Research on spatial diffusion of innovation has been concerned prima-

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[8]Innovation may be measured by the number of innovations or by the amount of resources devoted to innovative activities. However, it is usually measured by typical R&D measures such as patents, R&D employees, expenditures, and sales, primarily due to the problem of collecting data for innovations and of measuring incremental as well as radical innovations (Pavitt and Soete, 1980, p. 39).

rily with developing spatial models based on two major diffusion patterns, including general diffusion and hierarchical diffusion. The general diffusion pattern, which is commonly expressed by a distance-decay function, is represented by consumer innovation diffusion in rural areas (Hägerstrand, 1967). On the other hand, the hierarchical diffusion pattern, which describes the adoption by consumers and firms diffusing over space typically down the national or regional hierarchy from the leading city, is represented by central place and rank-size concepts (Berry, 1972; Hanham and Brown, 1976). However, both patterns have been employed in the diffusion models based on gravity concepts (Pederson, 1970; Malecki, 1977). Recently, Brown (1981) has synthesized these approaches in a "market and infrastructure" model of innovation diffusion.

Research on innovation diffusion seems to lack a broad conceptual framework within which various aspects of diffusion can be studied. Gold (1977; 1981) has identified several basic conceptual problems found in most studies on innovation diffusion. First, the number of plants or firms adopting an innovation or even the output associated with the innovation provides no basis for determining the rates of diffusion of the particular innovation being studied, because most innovations influence particular segments rather than the entire process of production (Gold, 1977; 1981). Second, changes in diffusion rates over time or differences in diffusion rates among industries may result from technological innovations rather than from the changes in the readiness of potential adopters, because they are likely to avoid types of innovations which may be replaced by improved products before long (Gold, 1981). Finally, changes in diffusion rates over time may also result from the changes in general economic conditions such as the change in business cycles, inflation levels, profit levels, and regulatory pressures (Gold, 1980). In short, many empirical studies have been prepared as individual descriptions rather than as broadly applicable generalizations of various aspects of innovation diffusion.

R&D and Technological Change

It has been widely accepted that R&D is the major source of technological change. Such a notion is based on many empirical studies which suggest that R&D leads to productivity growth and hence to technological change.[9] These studies, however, have been criticized for their basic conceptual weaknesses.

First, technological change has been measured usually by the change in some form of productivity, which determines essentially a physical input-output relationship within the neoclassical framework without considering the effect of quality improvement in either inputs or outputs (Gold, 1977). Second, R&D is only one of many factors of productivity growth. It may be an important contributor to productivity growth at the national level, but does not well explain obviously significant interindustry or interfirm differences in productivity growth (Nelson, 1981). Third, both the level of R&D

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[9]Productivity growth has traditionally been the most widely used measure of technological change. Productivity merely expresses in physical terms the relationship between the volume of output and the volume of resource inputs used in the production process. Productivity measures may be grouped into two broad classes. One includes those measures which relate output to a single type of input (such as labor or capital productivity), and the other includes those which relate output to a combination of inputs. Of these measures, a two-factor productivity which is frequently referred to as "total factor productivity" is the most widely used measure. It assumes technological substitutability between labor and capital in the production process, and measures the ratio of output to the two broad classes of tangible inputs, labor and capital (Kendrick, 1973, p. 14).

and productivity are strongly related to general economic conditions, such as inflation, unemployment, and regulatory pressures. Consequently, the changes in general economic conditions will alter the direct relationship between the two variables (Nelson, 1981).

Despite these and other shortcomings, evidence presented by a number of studies clearly indicates the significance of R&D on productivity growth in the private sector economy (Sveikauskas, 1981; Griliches, 1980; Denison, 1979; Nadiri, 1980). However, the evidence is not applicable to the effect of government-financed R&D on productivity growth in the private sector economy, which has not been clearly identified (Terleckyj, 1980; Kochanowski and Hertzfeld, 1981).

Regional Aspects of Technological Change

Research on technological change at the regional level has produced a number of empirical studies. Regional studies, however, have been concerned primarily with describing the spatial distribution of elements of technological change such as R&D, patents, and innovation, and with identifying the relationships between the elements of technological change and the factors affecting them at the regional level.[10]

Regional studies on patenting have focused on empirical analysis of the relationship between patents and urban factors affecting patent supply. Pred (1966) hypothesized that the number of inventions in a city is related to the size and industrial structure of the city. Feller (1971) tested Pred's hypothesis by analyzing the relationships between patents and popu-

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[10] Research on regional economic growth and technological change is reviewed mainly in Chapter III.

lation and manufacturing employment, respectively, and found strong correlations between patents and each explanatory variable. Higgs (1971) also identified strong correlations between per capita innovations and the percentage of urban population and the percentage of manufacturing employment. However, in an analysis of changes in these variables, Feller (1971) found the relationship between the patent growth rate and the urban population growth rate to be extremely weak.

Regional studies on R&D are characterized by their emphasis on the spatial distribution of R&D facilities and their locational determinants. Some studies identified R&D location in terms of locational relationships between city size and R&D labs, R&D personnel, and government R&D workers, respectively (Malecki, 1979; 1980c), and in terms of corporate structure and restructuring (Hill, 1978; Malecki, 1980b). Other studies identified the location of technical workers as the locational determinant of agglomeration of R&D facilities (Browning, 1980; Jones, 1975), and the location of government R&D facilities as a factor affecting the recent trend of R&D facilities toward decentralization (Malecki, 1979).

Regional studies on innovation and diffusion have been concerned with identifying the regional implications of innovation diffusion. In his study of best-practice firms in the Pacific Northwest plywood and veneer industry, Le Heron (1976) identified the important role played by best-practice firms in regional economic growth. Norton and Rees (1979) identified the core-periphery realignment process as the consequence of the spread of innovative capacity and rapid growth industries to the American South and West. Also, Oakey, Thwaites, and Nash (1980) attributed interregional variations in technological change in England to variations in the number of non-production workers.

Finally, a few regional studies have attempted to determine the relationship between labor productivity and population. Sveikauskas (1979) identified a significant correlation between labor productivity and city size in 14 selected industries. In addition, Casetti (1982) found a strong correlation between labor productivity growth and the growth in both population and manufacturing output in 50 U.S. states. In summary, labor, especially technical, non-production workers involved in R&D activities, has a large role in regional economic conditions, but it is a role that is not yet well understood.

CHAPTER III

REGIONAL GROWTH AND TECHNOLOGICAL CHANGE

The research of the past two decades on regional growth has resulted in the development of essentially two different types of models: the neoclassical regional growth models, and growth pole and related models. Neoclassical regional growth models assume a long-term interregional convergence in economic growth and a minor role of technological change in regional growth. On the contrary, the growth pole theory and related models are based on the notion of a long-term interregional divergence or unbalanced growth, and they make use of a dominant role for technological change in the regional growth process. This chapter reviews both types of models and presents an alternative approach to regional growth analysis.

Neoclassical Economic Growth Models

Neoclassical regional growth models originate from neoclassical models of aggregate national economic growth. Neoclassical economists tended to ignore the role of technological change in national economic growth until Solow (1957) and others found in their empirical studies[1] a signifi-

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[1]A group of economists conducted a series of studies on U.S. economic growth at the National Bureau of Economic Research (NBER) in the 1950s. In these studies, they attributed the growth of U.S. economy unaccounted for by the growth in labor and capital inputs to technological change (Terleckyj, 1980, p. 55).

cant contribution of technological change to U.S. economic growth. These studies led to the development of various forms of production functions based on typical assumptions about economic growth, such as 1) that firms as key productive actors transform inputs into outputs according to a production function, 2) that technological change is public, and 3) the factor and product markets are perfectly competitive (Nelson, 1981). Technology was assumed in the production functions to be either "embodied" in capital or labor inputs or "disembodied" from factor inputs. In addition, disembodied technology was assumed to be either capital-saving, labor-saving, or neutral (Kennedy and Thirlwall, 1972). Nelson (1981) considers most of these restrictive assumptions to be unrealistic "dead ends" in the study of technological change and economic growth.

However, much of the work on economic growth has been concerned with growth accounting implicit in the neoclassical work. This research has focused, first, on methods of estimating total factor productivity change as a measure of "residual growth" unaccounted for by the growth in labor and capital inputs (Jorgenson and Griliches, 1967). Second, it has attempted to identify explainable components of total factor productivity change, such as labor quality, resource allocation, economies of scale, and intensity of demand (Denison, 1979; Kendrick and Grossman, 1980). These studies have failed to eliminate unexplained residual growth, but they have identified "advances in knowledge" or technological change as the major component of residual growth (Denison, 1979; Kendrick and Grossman, 1980).[2]

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[2]Kendrick and Grossman (1980, pp. 16-17) have estimated that over 50 percent of the annual average growth rate in total factor productivity for 1948-1966 and 1966-1976 periods results from "advances in knowledge". Also, Denison (1979, p. 104) has found increasing ratios of advances in knowledge to the annual average national income for seven time periods between 1926 and 1976.

Neoclassical Regional Growth Models

Neoclassical regional growth models are essentially regional versions of neoclassical aggregate growth models modified by regional economists (Borts, 1960; Borts and Stein, 1964; Siebert, 1969) for the analysis of economic growth of open regional systems (Richardson, 1979). These models offer convenient explanations of endogenous system growth by assuming interregional factor flows (e.g., migration of labor and transfer of capital) which continue until factor returns are equalized in each region, and by assuming virtually no technological change and no spatial diffusion of technology (Richardson, 1973).[3] Siebert (1969) added some spatial considerations to neoclassical regional growth models, including polarization, environmental factors, transportation, and spatial diffusion of technology, in order to give a more explicit explanation of interregional factor flows. However, he included technological change in his "eclectic" model as a minor and less operational factor in comparison with capital and capital (Malecki, 1983a). Consequently, the neoclassical regional growth models developed on the basis of such assumptions as interregional growth convergence and the minor role of technological change failed to explain the characteristics of regional economies and the imbalances evident in sectoral and spatial economic growth phenomena and in spatial diffusion of technology (Richardson, 1979; Todd, 1974). Eventually, these problems led many researchers to accept growth pole concepts as an alternative framework for

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[3] Neoclassical regional growth models assume regionally identical production functions with constant returns to scale, a fixed labor supply, no technological change, perfect competition, full employment, and wages as a direct function of the capital labor ratio (Richardson, 1979, p. 137).

explaining unbalanced interregional growth.

Unbalanced Interregional Growth Models

Unbalanced interregional growth models include growth pole theory, cumulative causation, and core-periphery models. The last two concepts are less well developed (Richardson, 1979), but they are indirectly related to growth pole concepts (Parr, 1973). Fundamentally, all of these models assume an essential role of technological change in polarized or divergent interregional economic growth.

The unbalanced interregional growth models assume the emergence of what can be called a growth pole through the process of a circular and cumulative growth of firms and industries in the pole.[4] Local economic growth is initiated by a single firm or an industry which dominates the economy. With the growth of local demand, the firm or industry expands its output, diversifies its product, substitutes imports for products produced by local suppliers, and exports its products to other regions (Thompson, 1965). This leads to the expansion of the service sector, economic specialization, the formation of industrial linkages and eventually to self-sustained local

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[4] The growth pole concept was developed by Perroux (1955) on the basis of Schumpeter's (1934) concept of innovation as a main source of economic growth. Perroux defined a growth pole as a set of industries strongly interrelated to each other through input-output linkages around a leading ("propulsive") industry which grows faster than the rest of the economy because of advanced technological practice and high innovation rates, higher income elasticities of demand for its products and large spill-over and multiplier effects on other segments of the economy (Richardson, 1979, pp. 164-165). Many theorists modified Perroux's original growth pole concept by translating economic space into geographical space in order to broadly define a growth pole as a geographical clustering of economic activity in general (Richardson, 1979, p. 165) or simply as an urban growth center or a nodal point (Parr, 1973, p. 176). Outside of regional research, Nelson and Winter's (1982) "evolutionary theory of economic change" also draws upon Schumpeter's work and its emphasis on innovation.

economic growth (Pred, 1966). This process is reinforced by another sequence of events, the adoption of innovations and industrial expansion which enhances the status of the local economy from a local town to a regional center or a growth pole which dominates economically neighboring cities (Pred, 1966; Thompson, 1965).

The growth pole is assumed to grow faster than the rest of its region due to the increase in demand, output expansion, the increase in profit, utilization of new technology, agglomeration of industries, and the subsequent reduction in input and output costs (Thomas, 1975). The output of this process is a polarization with a growth pole dominating the economy of its hinterland. The growth of the pole has both spread (diffusion) and backwash (polarization) effects upon its hinterland (Myrdal, 1957). The spread effects, such as increased hinterland production, improved service provision, and the decentralization of economic activity from the pole, are favorable to the hinterland, while the backwash effects, such as centralization of production, consolidation of points of service provision, and migration of skilled labor to the pole, are unfavorable to the hinterland (Parr, 1973). The combination of these two types of effects determines the degree of polarization within a region from a growth pole.[5]

The unbalanced interregional growth models assume a critical role of technology in interregional growth divergence. It divides regions into cores and peripheries on the basis of their innovative capacity. Core regions are characterized by a high capacity of generating and absorbing innovations (Friedmann, 1972), and by their being specialized in the innovative phase of the product life cycle which allows them to generate new firms and jobs

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[5]For a recent review of this process, see Gaile (1980).

(Vernon, 1966; Malecki, 1981). Peripheral regions, on the contrary, have little innovative capacity and tend to be specialized in the standardized phase of the product cycle, which usually "deskills" local production jobs (Malecki, 1983a). The growth disparity between core and peripheral regions increases over time, because the core regions reinforce their dominance over the peripheral regions by encouraging the flow of natural, labor, and capital resources from peripheral to core regions, by enhancing the opportunities for continuous innovative activities, and by making the peripheral regions dependent on the core regions for growth (Friedmann, 1972).[6]

The unbalanced interregional growth models as reviewed in this section are concerned primarily with short-term quantitative effects rather than long-term qualitative effects of technological change on regional economic structure (Thomas, 1975). The structural change assumed by the growth pole theory is essentially a short-term quantitative change in output by lead firms or propulsive industries, rather than a long-term qualitative change in input-output linkages (Thomas, 1975).

Dual Roles of Technological Change in Regional Growth

Both the neoclassical approach to regional growth analysis and growth pole concepts have failed to identify fully the relationship between regional growth and technological change. Recently, however, Thomas (1975) has developed an alternative approach to regional growth analysis by hypothesizing dual roles of technological change in regional growth.

Conditions for Long-Term Regional Economic Growth

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[6]A direct analogy in international trade and growth is presented by Krugman (1979).

Thomas (1975) argues that growth pole concepts are concerned essentially with a short-term effect of process technology only rather than a long-term combined effect of both process and product technologies on regional growth. He hypothesized that two conditions must be satisfied, if long-term regional or national economic growth is to take place. One is that demand for commodities must be elastic. Under this condition, an increase in the supply of one commodity would lead to the increase in the demand for other commodities. The other is that returns must increase, so that an increase in return can lead to an increase in demand (Thomas, 1975, p.12).

Thomas (1975) assumes that the dual roles of technological change (e.g., productivity improvement and production of new and improved products) satisfy the two conditions, because productivity improvement contributes to increasing returns which inturn provide a stimulus to a long-term expansion of output and to the production of new and improved products which would lead to changes in the composition of industries.

The dual roles of technological change are interpreted as the two roles a technology plays in production. In fact, process technologies for one firm are often found to be the product technologies of other firms, usually in other industries (Thomas, 1981; Scherer, 1982b). But it is not likely that all technologies play the two roles in regional growth. A typical example is the technology produced by the drug industry, which is almost totally product-oriented (Scherer, 1982b).

Product Technology and New and Improved Products

Product technology is developed and used to discover and exploit new products and to make minor improvements in existing products so that innovative firms can open new markets for new products or extend their existing markets (Malecki, 1983b). In this respect, product technology is more important than process technology. In fact, product technology is where firms concentrate their R&D efforts and allocate most R&D funds (Malecki, 1983b; Scherer, 1982b).

However, only new products are usually identified as new sources of employment and new industry growth. Therefore, new jobs in large numbers can be expected only from significant technologies that have widespread application (Rothwell, 1981). The improvement of existing products seldom affects employment, because it requires minimum R&D efforts and only minor adjustment to the users of the products.

The level of job skills associated with the production of new products varies with the stage of product development. New product development requires a large number of R&D workers in the innovation stage at R&D centers, and a large number of skilled workers in the standardization stage. However, mainly low-skilled workers are employed in the mature stage, and they are frequently sought out away from high-cost urban areas (Malecki, 1983b).

Process Technology and Productivity Growth

It is well known that process technology is the major source of productivity growth. Neoclassical economists and growth pole theorists have emphasized the importance of process technology for regional economic growth (Thomas, 1975). It is not so well known, however, that process technology is closely related to product technology as previously mentioned in this chapter. Moreover, the benefits of growth in process technology are not necessarily translated into increased employment opportunities.

Schmookler viewed the "production" (process) technology of an industry as dependent upon "the combined effect of product technologies of many different industries which supply products as inputs to it" (Schmookler, 1966, p. 101) and emphasized the importance of product innovations for the development of process technology through input-output linkages.

Productivity growth as the role of process technology has traditionally been related to cost-savings or profitability which usually means a reduction in employment. The productivity gains resulting from fewer workers allow jobless growth which characterizes recent economic growth in many industrialized countries (Rothwell, 1981).

In summary, the failure of neoclassical regional growth models and unbalanced interregional growth models to articulate the role of technological change in regional economic growth has led to the development of the concept of dual roles of technological change. The concept emphasizes the importance of product technology and its effect on process technology for a long-term, self-sustained regional economic growth. The following chapter examines the regional variations in state patenting activity as a crude indicator of state technology level.

CHAPTER IV

THE REGIONAL DISTRIBUTION OF STATE PATENTING ACTIVITY

Patents as a proxy measure of innovative activity have been studied at the state level only for historical periods such as 1870-1970 (Higgs, 1971), and for one other period since 1920 in a study by Thompson (1962) of 1952-1954 patent data. With new state patent data, which have been published since 1977, this chapter presents the regional distribution of state patenting activity and its intensity before the hypothesis concerning the dual roles of technological change is tested.[1]

Measures of State Patenting Activity and Its Intensity

The regional distribution of state patenting activity was described by identifying the regional variations in state patenting activity and its intensity, and by explaining statistically the variations with the factors affecting them. The state patenting activity was measured by the number of state patents, and the intensity of state patenting activity was measured by the number of state patents per million state population. The state

[1]State patents refer to those patents which are granted to the residents and corporations of each state. They must be distinguished from the utilized patents of each state as used for the test of the hypothesis in this study. The utilized patents are likely to include a large number of out-of-state patents. Also, state patenting activity refers to the inventive activity which leads to patentable inventions. In this study, it was measured by the number of state patents, and only for the period since 1925.

patent data were obtained from the U.S. Department of Commerce, Patent and Trademark Office (1977; 1982).[2] In addition, the state population data were drawn from the Statistical Abstract of the United States which is published annually by the U.S. Bureau of the Census.

The factors affecting state patenting activity (followed by the codes used in this study) include: state population in thousand (PP), the number of R&D laboratories (LB), the number of central administrative offices (CO), the number of employees with central administrative offices (COE), and the number of employees in high and intermediate technology industries in thousand (EHT). The data for the last four variables were collected from Industrial Research Laboratories of the United States, Enterprise Statistics, and the Annual Survey of Manufactures.[3] The four variables, after being normalized by population (LBP, COP, COEP, and EHTP), were used as the factors affecting the intensity of state patenting activity (PTP).

Regional Variations in State Patenting Activity

The development of patenting activity in the United States between 1925 and 1980 is characterized by three distinctive phases: a sharp decline

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[2]Technology Assessment and Forecast: 7th Report (U.S. Department of Commerce, Patent and Trademark Office, 1977, pp. 187-195) provides state patent data in time series from 1883 to 1976, and some unpublished tabulations obtained from the U.S. Patent and Trademark Office (1982) provide more recent patent data for each year between 1977 and 1980.

[3]Jaques Cattell Press, ed., Industrial Research Laboratories of the United States (12th, 14th, and 16th eds.; New York: Bowker, 1965, 1975, and 1979); U.S. Bureau of the Census, Enterprise Statistics for 1963, 1972, and 1977, Central Administrative Offices and Auxiliaries, pt. 2; U. S. Bureau of the Census, Annual Survey of Manufactures for 1964-1965, 1975, and 1978. The data for the number of R&D laboratories and the number of central administrative offices (CAOs) are available for selected years in Industrial Research Laboratories of the United States and Enterprise Statistics, respectively. However, the data for CAO employees are available for 1977 only.

between 1925 and 1950 due to the Great Depression, World War II, and its aftermath, a vigorous growth between 1950 and 1975 (Rosegger, 1980, pp. 175-176), and then again a sharp decline between 1975 and 1980 probably due to the stagnated economy after the 1974 oil embargo.

At the regional level, there have been some significant changes in the distribution of state patenting activity. Historically, patenting activity in the United States has been dominated by eight states with major urban centers. They are California and seven major states in the Northeast and the East North Central Region including New York, Illinois, Pennsylvania, Ohio, New Jersey, Massachusetts, and Michigan, as shown in Table 1. These seven states shared 60.0% of the national total patents in 1950, but their share fell to 48.5% in 1980. On the other hand, California's share continued to increase sharply (from 9.2% in 1950 to 13.9% in 1980), and Texas emerged as one of the major patent producers with its share of 4.5% in 1975.

Generally, most states in the West and South steadily increased their shares between 1950 and 1980 at the expense of states in the Northeast and the East North Central Region. This trend of the decline of northern states and the growth of southern and western states in patenting activity corresponds to the regional shifts in manufacturing activity, which is attributable in part to the redistribution of population to the South and West following the dispersion of northern manufacturing industries (Norton and Rees, 1979).

Regional Variations in the Intensity of State Patenting Activity

The intensity of state patenting activity as measured by the number of state patents per million population has been used by Higgs (1971) and others to indicate the inventiveness of state residents. The analysis of

TABLE 1

NUMBER OF PATENTS BY STATE, 1925 - 1980

STATE	PT25	PT50	PT75	PT80	PTS50	PTS75	PTS80
AL	178	134	250	204	0.3	0.5	0.5
AK	11	12	42	25	0.0	0.1	0.1
AZ	65	93	487	486	0.2	1.0	1.2
AR	110	72	84	86	0.2	0.2	0.2
CA	3,067	3,990	6,780	5,588	9.2	13.5	13.9
CO	405	284	600	544	0.7	1.2	1.4
CT	1,283	1,468	1,677	1,205	3.4	3.3	3.0
DE	51	332	490	289	0.8	1.0	0.7
DC	395	348	89	49	0.8	0.2	0.1
FL	207	323	1,061	1,141	0.7	2.1	2.8
GA	239	214	376	367	0.5	0.8	0.9
HI	35	31	63	34	0.1	0.1	0.1
ID	86	68	111	82	0.2	0.2	0.2
IL	4,629	4,229	3,955	2,994	9.8	7.9	7.4
IN	985	1,117	1,139	933	2.6	2.3	2.3
IA	610	371	386	340	0.9	0.8	0.8
KS	445	246	371	267	0.6	0.7	0.7
KY	255	152	339	281	0.4	0.7	0.7
LA	213	231	392	308	0.5	0.8	0.8
ME	131	76	68	68	0.2	0.1	0.2
MD	447	671	1,004	729	1.5	2.0	1.8
MA	2,332	1,912	2,038	1,659	4.4	4.1	4.1
MI	1,910	2,417	2,761	2,227	5.6	5.5	5.5
MN	800	698	1,080	910	1.6	2.2	2.3
MS	91	59	106	76	0.1	0.2	0.2
MO	1,110	780	698	677	1.8	1.4	1.7
MT	177	63	54	63	0.1	0.1	0.2
NE	325	129	145	106	0.3	0.3	0.3
NV	19	36	98	91	0.1	0.2	0.2
NH	152	86	182	168	0.2	0.4	0.4
NJ	2,580	3,701	3,909	3,073	8.5	7.8	7.6
NM	48	57	117	122	0.1	0.2	0.3
NY	7,460	7,209	4,909	3,637	16.6	9.8	9.0
NC	177	248	558	538	0.6	1.1	1.3
ND	105	38	38	31	0.1	0.1	0.1
OH	3,610	3,412	3,179	2,313	7.9	6.3	5.7
OK	432	494	717	636	1.1	1.4	1.6
OR	308	294	354	331	0.7	0.7	0.8
PA	3,956	3,099	3,538	2,570	7.2	7.1	6.4
RI	345	409	214	149	0.9	0.4	0.4
SC	103	98	251	226	0.2	0.5	0.6
SD	130	43	46	25	0.1	0.1	0.1
TN	246	294	391	397	0.7	0.8	1.0
TX	834	992	2,246	1,885	2.3	4.5	4.7
UT	150	70	238	220	0.2	0.5	0.5
VT	64	66	82	63	0.2	0.2	0.2
VA	287	356	671	538	0.8	1.3	1.3
WA	641	480	553	536	1.1	1.1	1.3
WV	278	162	142	140	0.4	0.3	0.3
WI	1,271	1,114	978	787	2.6	2.0	2.0
WY	80	32	32	38	0.1	0.1	0.1

Note: PT is the number of state patents, and PTS is the state share of national total patents. The two digit numbers after variable names indicate the years for the values of these variables.

Sources: U. S. Patent and Trademark Office, Technology Assessment and Forecast: 7th Report. (Washington, D. C.: U. S. Government Printing Office, 1977), pp. 187-195; and Unpublished tabulations obtained from the Patent and Trademark Office in 1982.

the data on the intensity of state patenting activity from 1950 to 1980 (Table 2) indicates that the regional variations in intensity are different from those of the absolute number of state patents.

First, three states, including Delaware, New Jersey, and Connecticut, led other states in the intensity of state patenting activity during the period. California, Minnesota, and Oklahoma and six of the seven major northern states (including New York, Illinois, Pennsylvania, Ohio, Massachusetts, and Michigan) showed much lower intensities of the state patenting activity, although their intensities were higher than those of other remaining states (Map 1). One possible explanation for the high intensities of the nine states is that the ratio of high technology industries to low technology industries was much higher in these states than in other states during the same period, as can be estimated from the employment data in the Annual Survey of Manufactures. A second explanation, which is more difficult to prove in a study of this type, is that some major patenting firms (such as Phillips Petroleum in Bartlesville, Oklahoma) influence the state level data.

Second, all states in the Northeast, the West, and the North Central Regions except South Dakota, Colorado, New Mexico, Utah, Alaska, and Hawaii experienced a decline, while all states in the South (except Maryland, Delaware, West Virginia, and Washington, D.C.) experienced growth in the intensity of state patenting activity between 1950 and 1980. This indicates that the regional distribution of patenting activity has shifted toward the South. Finally, all 50 states and Washington, D.C. experienced a decline in patenting intensity during the last five-year period (1975-1980), which corresponds to the trend of state patenting activity for the same period.

TABLE 2

INTENSITY OF STATE PATENTING ACTIVITY BY STATE, 1950 - 1980

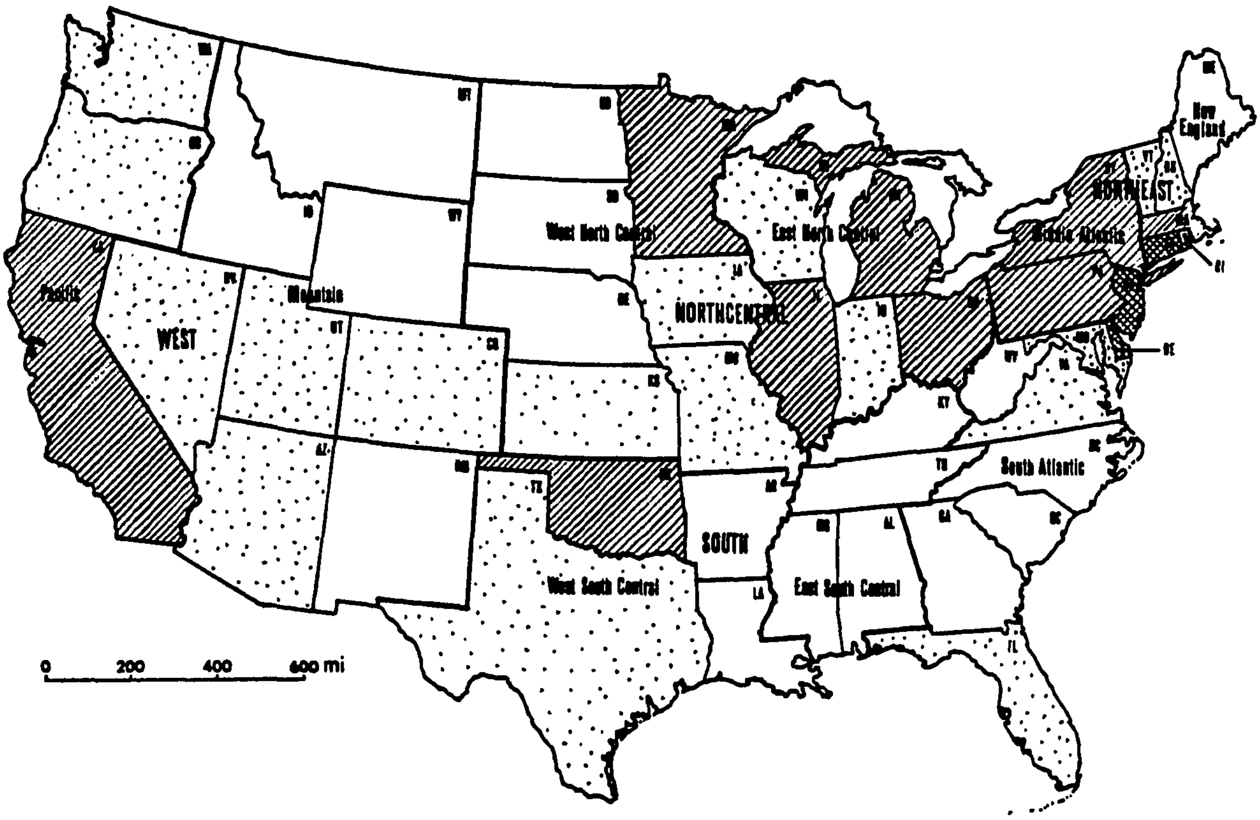
STATE	PTP50	PTP75	PTP80	PTPR5075	PTPR7580
AL	43.8	67.9	52.4	55.2	-22.8
AK	93.0	113.5	62.5	22.0	-44.9
AZ	124.0	213.0	178.8	71.8	-16.1
AR	37.7	38.9	37.6	3.3	-3.3
CA	376.9	314.8	236.1	-16.5	-25.0
CO	214.3	232.0	188.2	8.2	-18.9
CT	731.4	543.6	387.8	-25.7	-28.7
DE	1,044.0	831.9	484.9	-20.3	-41.7
DC	433.9	125.4	76.8	-71.1	-38.7
FL	116.6	124.2	117.2	6.6	-5.7
GA	62.1	74.3	67.2	19.6	-9.6
HI	62.0	71.3	35.2	14.9	-50.6
ID	115.4	133.4	86.8	15.6	-35.0
IL	485.4	349.8	262.2	-27.9	-25.0
IN	283.9	212.9	169.9	-25.0	-20.2
IA	141.5	134.0	116.7	-5.3	-12.9
KS	129.1	162.8	113.0	26.1	-30.6
KY	51.6	97.7	76.8	89.3	-21.5
LA	86.1	100.8	73.3	17.2	-27.3
ME	83.2	63.4	60.4	-23.8	-4.6
MD	286.4	241.5	172.9	-15.7	-28.4
MA	407.6	353.7	289.2	-13.2	-18.2
MI	379.3	303.1	240.5	-20.1	-20.7
MN	234.1	275.1	223.2	17.5	-18.9
MS	27.1	44.2	30.2	63.1	-31.7
MO	197.2	145.6	137.7	-26.2	-5.4
MT	106.6	72.1	80.1	-32.4	11.0
NE	97.3	94.1	67.5	-3.3	-28.2
NV	225.0	158.1	113.9	-29.7	-27.9
NH	161.4	219.3	182.4	35.9	-16.8
NJ	765.5	532.5	417.3	-30.4	-21.6
NM	83.7	100.6	93.9	20.2	-6.6
NY	486.1	272.2	207.2	-44.0	-23.9
NC	61.1	100.8	91.6	65.1	-9.1
ND	61.3	59.6	47.4	-2.8	-20.4
OH	429.3	295.2	214.2	-31.3	-27.4
OK	221.2	258.7	210.2	16.9	-18.7
OR	193.3	152.3	125.8	-21.2	-17.4
PA	295.2	297.4	216.6	0.7	-27.2
RI	516.4	226.2	157.2	-56.2	-30.5
SC	46.3	86.6	72.5	87.0	-16.3
SD	65.8	67.5	36.2	2.6	-46.4
TN	89.3	91.8	86.5	2.7	-5.8
TX	128.6	178.7	132.5	38.9	-25.9
UT	101.6	192.9	150.6	89.8	-21.9
VT	174.6	170.8	123.0	-2.2	-28.0
VA	107.3	132.7	100.6	23.7	-24.2
WA	201.8	152.8	129.8	-24.3	-15.1
WV	80.8	77.1	71.8	-4.5	-6.9
WI	324.3	214.0	167.2	-34.0	-21.9
WY	110.0	84.2	80.7	-23.4	-4.2

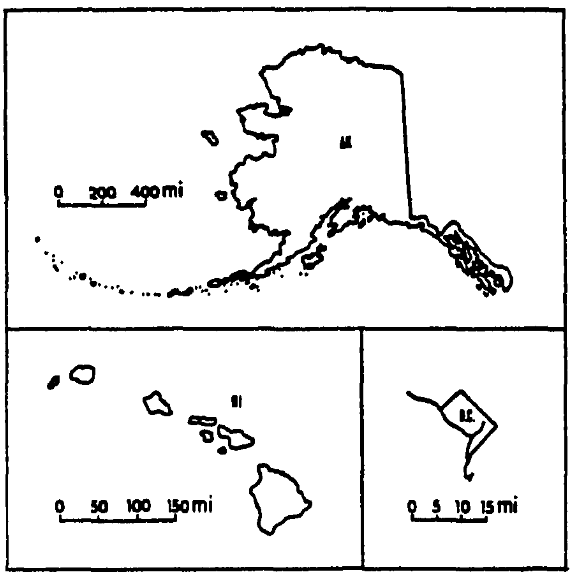
Note: PTP is the number of state patents per million state population, and PTPR is the rate of change in PTP. The two digit numbers after variable names indicate the years for the values of these variables.

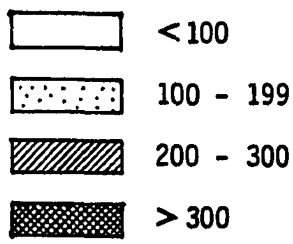
Sources: U. S. Patent and Trademark Office, Technology Assessment and Forecast: 7th Report. (Washington, D. C.: U. S. Government Printing Office, 1977), pp. 187- 195; Unpublished tabulations obtained from the Patent and Trademark Office in 1982; and U. S. Bureau of the Census, Statistical Abstract of the United States: 1960 and 1980.

MAP 1

STATE PATENTS PER MILLION POPULATION, 1980 (PTP80)







Source: Table 2.

Factors Affecting State Patenting Activity and Its Intensity

It has been assumed that patenting activity is essentially an urban phenomenon (Pred, 1966). Previous empirical studies have tested this assumption and identified the close relationship between patents and population at the city level (Feller, 1971; Higgs, 1971). The strong correlation between patents and population is also found at the state level, as indicated by the results of Equations 1 through 7 in Table 3. The regression coefficients of population are highly significant in all seven equations. Also, the coefficients of determination (R^2) increased from 80.9 % to 86.5 % from 1950 to 1980.

Patenting activity as a measure of R&D output has been found to be closely related to the R&D input measures such as the number of scientific personnel and R&D expenditures at the national and international levels (Pavitt and Soete, 1980; Pavitt, 1982). The relationships between patenting activity (PT) and four R&D input measures are also found to be significant at the state level, as shown by the results of Equations 8 through 16 in Table 3. The four R&D input measures are: the number of R&D labs (LB), the number of central administrative offices (CO), the number of employees with central administrative offices (COE), and the number of employees in high and intermediate technology industries in thousand (EHT).

Two of the variables, LB and COE, show remarkably significant correlations with PT. Each explains over 90% of total variation in patenting activity, higher in each case than the relationship with population. Other two variables (CO and EHT), however, show less significant correlations with PT. The significant individual correlations between PT and the four independent variables may be attributed to the effect of population on them,

TABLE 3

STATE PATENTS AND THE FACTORS AFFECTING STATE PATENTING ACTIVITY

Regression Equation	Dependent Variavle	Constant	Coefficient	Independent Variable	R^2
1	PT50	-394.55	0.42 (14.42)	PP50	0.809
2	PT55	-198.44	0.24 (15.62)	PP55	0.833
3	PT60	-305.45	0.32 (16.35)	PP60	0.845
4	PT65	-365.71	0.37 (17.70)	PP65	0.865
5	PT70	-305.71	0.32 (17.65)	PP70	0.864
6	PT75	-279.50	0.30 (17.68)	PP75	0.864
7	PT80	-199.70	0.22 (17.68)	PP80	0.865
8	PT65	122.11	10.80 (24.92)	LB65	0.927
9	PT65	6.94	4.66 (14.50)	CO63	0.811
10	PT65	-23.58	12.23 (21.33)	EHT65	0.903
11	PT75	73.24	7.75 (26.22)	LB75	0.933
12	PT75	-21.94	3.07 (16.42)	CO72	0.846
13	PT75	-26.22	11.33 (22.77)	EHT75	0.914
14	PT79	23.91	3.36 (21.25)	LB79	0.902
15	PT79	43.35	0.02 (23.32)	COE77	0.917
16	PT79	-20.47	6.31 (20.72)	EHT78	0.898

Note: The dependent variable in this table is the number of state patents (PT). Independent variables include state population in thousand (PP), the number of R&D labs (LB), the number of central administrative offices (CO), the number of employees with central administrative offices (COE), and the number of employees in high and intermediate technology industries in thousand (EHT). t-values are given in parentheses. All correlation coefficients are significant at the 0.001 level.

Sources: U. S. Patent and Trademark Office, Technology Assessment and Forecast: 7th Report (Washington, D. C.: U. S. Government Printing Office, 1977), pp. 187-195; Unpublished tabulations obtained from the Patent and Trademark Office in 1982; Jaques Cattell Press, ed., Industrial Research Laboratories of the United States: 12th, 14th, and 16th eds. (New York: Bowker; 1965, 1976, and 1979); U. S. Bureau of the Census, Enterprise Statistics: 1963, 1972, and 1977, Central Administrative Offices and Auxiliaries, pt. 2; U. S. Bureau of the Census, Annual Survey of Manufactures: 1964-1965, 1975, and 1978; and U. S. Bureau of the Census, Statistical Abstract of the United States: 1961, 1966, 1971, and 1981.

but the higher explanatory power of the R&D input measures suggests that the amount of economic activity in a state, not simply its population, accounts best for the geographic pattern of patenting.

When the effect of population is eliminated by normalizing the dependent and independent variables with state population, the correlations between the dependent variable (PTP) and each of the four independent variables including LBP, COP, COEP, and EHTP become less significant as indicated by the results of Equations 1 through 9 in Table 4.[4] However, LBP and COEP still show much more significant correlations with PTP than the other two independent variables. Each of them alone explains over 50% of total variation in PTP. The close relationships between PTP and LBP and COEP can be easily identified even by comparing PTP80 in Map 1 with LBP79 in Map 2 and COEP77 in Map 3. The relative importance of LBP and COEP over COP and EHTP is also clear in the following three multiple regression equations (t-values are in parentheses):

$$PTP65 = 63.93 + \underset{(5.51)}{7.87(LBP65)} + \underset{(1.67)}{2.42(EHTP65)} - \underset{(0.63)}{0.47(COP63)}; \quad R^2=0.605$$

$$PTP75 = 57.70 + \underset{(4.47)}{5.55(LBP75)} + \underset{(1.18)}{1.86(EHTP75)} - \underset{(0.37)}{0.24(COP72)}; \quad R^2=0.527$$

$$PTP79 = -8.97 + \underset{(7.88)}{0.01(COEP77)} + \underset{(4.14)}{2.00(EHTP78)} + \underset{(3.81)}{0.74(LBP79)}; \quad R^2=0.805$$

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[4]State patenting activity was transformed into the intensity of state patenting activity (PTP) by normalizing it with one million state population. The four independent variables normalized by population include: the number of R&D labs per million population (LBP), the number of central administrative offices per million population (COP), the number of employees with central administrative offices per thousand population (COEP), and the number of employees in high and intermediate technology industries per million population (EHTP). Due to the lack of data, COP was employed for 1963 and 1972, and COEP for 1977 only.

TABLE 4

INTENSITY OF STATE PATENTING ACTIVITY AND THE FACTORS AFFECTING THE INTENSITY

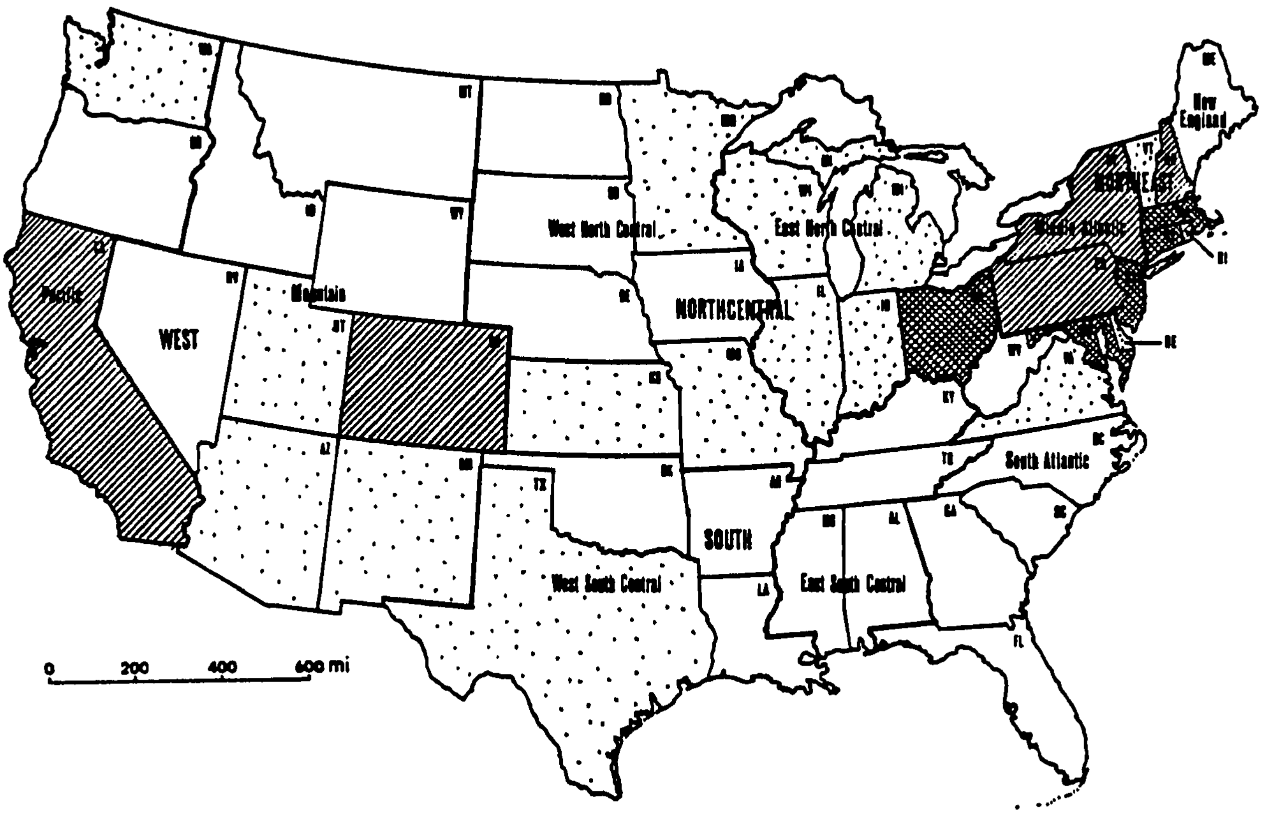
Regression Equation	Dependent Variable	Constant	Coefficient	Independent Variable	R^2
1	PTP65	63.54	8.57 (8.06)	LBP65	0.570
2	PTP65	106.51	1.83** (1.92)	COP63	0.070
3	PTP65	99.37	6.99 (4.43)	EHTP65	0.286
4	PTP75	59.79	5.94 (7.11)	LBP75	0.508
5	PTP75	60.66	1.77* (2.62)	COP72	0.123
6	PTP75	95.11	6.20 (3.86)	EHTP75	0.233
7	PTP79	57.75	1.60 (5.08)	LBP79	0.345
8	PTP79	30.57	0.02 (9.41)	COEP77	0.644
9	PTP79	42.23	4.12 (5.36)	EHTP78	0.370

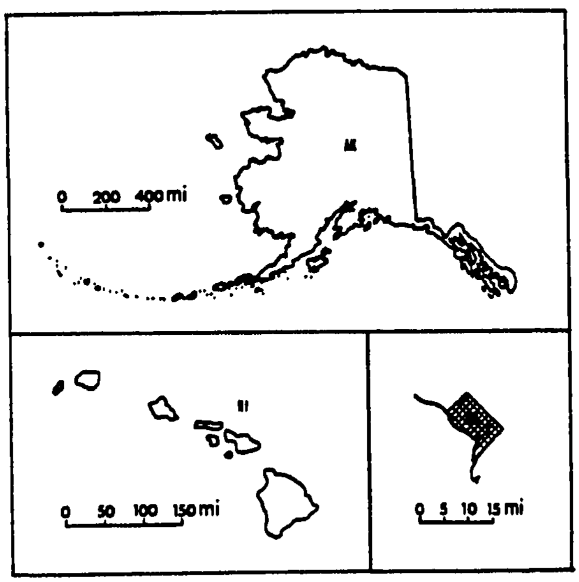
Note: See Footnote 2 in this chapter for dependent and independent variables. t-values are given in parentheses. All correlation coefficients are significant at the 0.001 level, unless indicated otherwise. * indicates the significance at the 0.05 level, and ** indicates the significance at the 0.10 level.

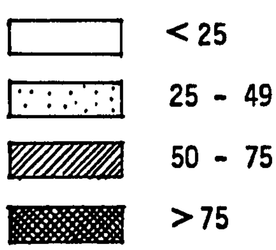
Sources: Same as Table 3.

MAP 2

R&D LABS PER MILLION POPULATION, 1979 (LBP79)



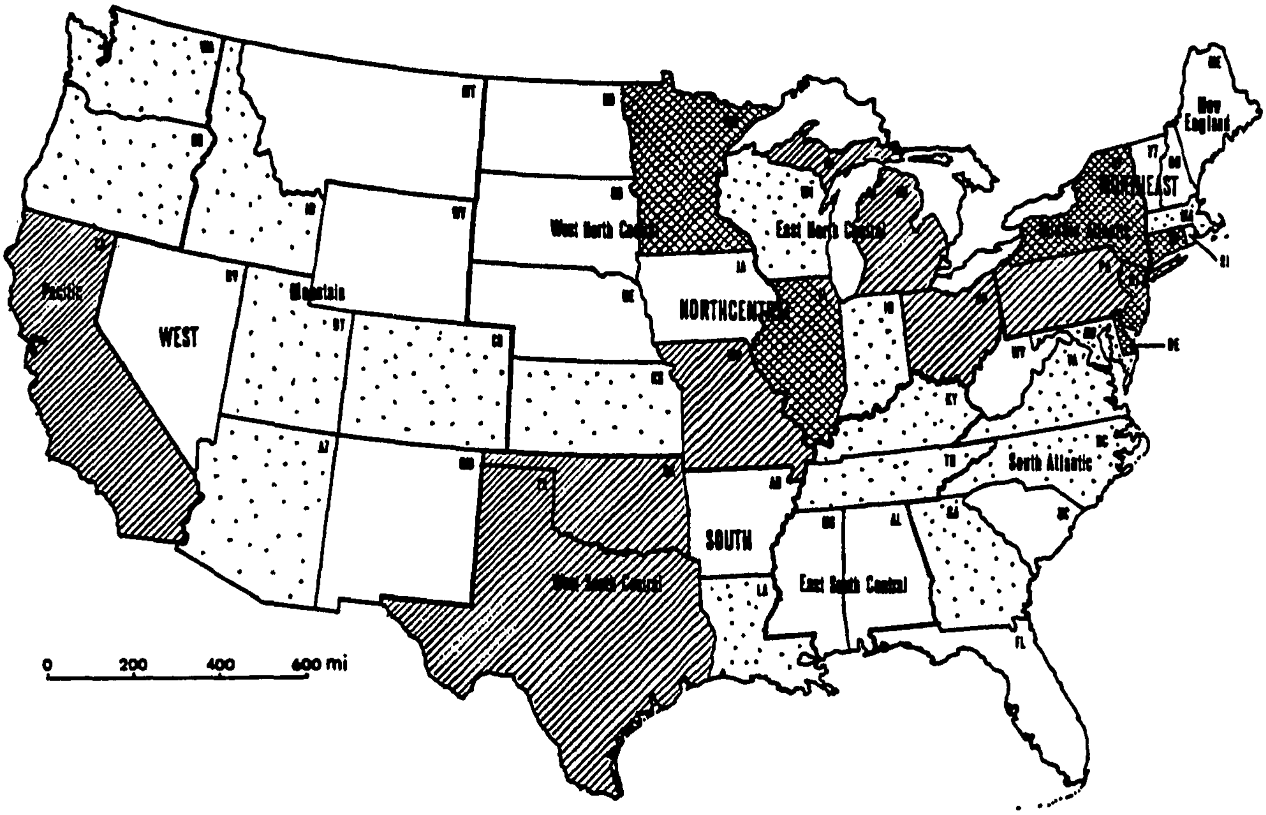


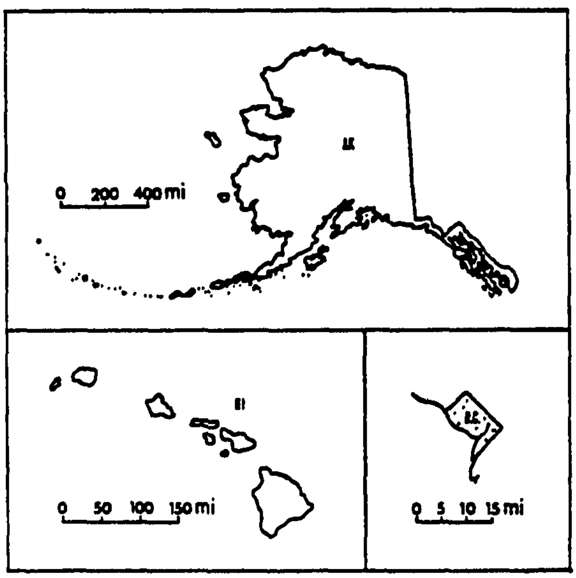


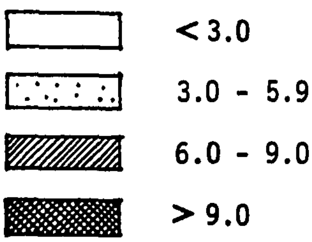
Source: Jaques Cattell Press, ed., <u>Industrial Research Laboratories of the United States</u>. 16th ed. 1979.

MAP 3

EMPLOYMENT WITH CENTRAL ADMINISTRATIVE OFFICES
PER THOUSAND POPULATION, 1977 (COEP77)







Source: Jaques Cattell Press, ed., Industrial Research Laboratories of the United States. 16th ed. 1979.

The independent variables in the above three equations explain fairly well the interstate variations in PTP for 1965, 1975, and 1979. Analysis of the residuals from regression provides information about which observations (states) are poorly explained by the equations. The three independent variables in the first equation overpredict PTP65 in Washington, D.C. only and underpredict it in Delaware, Minnesota, and Oklahoma.[5] The independent variables in the second equation overpredict PTP75 in Washington, D.C., Massachusetts, and New Hampshire and underpredict it also in Delaware, Minnesota, and Oklahoma. On the other hand, the independent variables in the third equation overpredict PTP79 in Washington, D.C., Georgia, Hawaii, Missouri, and Ohio and underpredict it in Connecticut, Nevada, New Jersey, Vermont, Utah, and Wyoming.

Generally, for the first two equations, these residuals identify the states which have a large number of corporate headquarters, especially of firms with a high propensity to patent, and tend to underpredict their patenting intensity. Overpredicted states tend to have a relatively smaller number of R&D labs than is reflected in the intensity of state patenting activity (e.g., Washington, D.C.). The third equation is more difficult to assess, since it also had to employ a different measure for central administrative offices (COEP rather than COP). Curiously, this equation had a higher R^2 value than those for earlier years that used COP.

These regional patterns of patenting in the United States have been

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[5]In this study, the observed values of dependent variables were classified as overpredicted values, if they are less than their predicted values by less than -1 SE (standard error of estimate). On the contrary, they were classified as underpredicted values, if their observed values are greater than their predicted values by more than +1 SE.

shown to be closely related to population, as suggested by historical studies. However, when indicators of economic activity related to patenting are used, such as industrial R&D laboratories, central administrative offices and employees, and employees in high and intermediate technology sectors, the level of explanation is even greater. It can be generalized that patenting activity is greater in states with larger populations, larger numbers of R&D labs, central administrative office employees, and high technology labor forces. These factors account rather well for the distribution of patenting. The economic effect of patenting, in terms of utilization of patents, is the focus of the next two chapters.

CHAPTER V

RESEARCH METHODOLOGY

Chapters II and III identified the shortcomings of the conventional approaches to regional growth analysis and presented the concept of dual roles of technological change as suggested by Thomas (1975) as an alternative approach. This chapter establishes an hypothesis on the basis of the concept of dual roles of technological change and presents the variables, data, assumptions, and methods used in testing the hypothesis.

Research Goal

The analysis of the research of the past two decades on technological change and economic growth indicates a dominance by neoclassical approaches and a search for alternative approaches as a reaction to many conceptual problems of neoclassical approaches. One alternative approach has recently been suggested by Thomas (1975), who has developed the concept of dual roles of technological change for regional growth analysis. The dual roles include the regional economic growth determined by productivity growth and the growth from new products (or new industry and new employment) as the result of the changes in regional process and product technologies. The concept has not yet been tested empirically, due to the lack of a suitable technology measure. Fortunately, Scherer (1982b) has recently made it possible to test the concept by providing a measure of product technology in his study of R&D utilization.

On the basis of the concept of dual roles of technological change, it was hypothesized that interstate variations in the growth rate of state manufacturing output in the United States are determined by the rates of change in state process and product technologies.[1] The goal of this study is to test this hypothesis. This test, however, is preceded by the analysis of the two separate relationships between the growth rate of state manufacturing output and the rates of change in state process and product technologies.

Measures of Technological Change and Manufacturing Output Growth

The rate of change in state process technology was measured by the rate of change in state total factor productivity (TPR) and also by the rate of change in the estimated number of patents utilized as process technology (PCR). On the other hand, the rate of change in state product technology was measured by the rate of change in the estimated number of patents utilized as high and intermediate product technology (PDRH) and also in the estimated number of patents utilized as low product technology (PDRL). Finally, the growth rate of state manufacturing output was measured by the rate of change in the state total of value-added in manufacturing (VAR).

Patent Utilization Rates

In this study, patent utilization rates were estimated on the basis of Scherer's (1982b, pp. 232-241) interindustry technology flow matrix,

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[1]The hypothesis was tested with a population of 51, comprised of the 50 U.S. states and the District of Columbia.

which indicates the interindustry input-output relationships in R&D expenditures and use. From the matrix, R&D utilization rates were estimated for selected industries, as shown in Table 5. The R&D utilization rates in the table were used as patent utilization rates, assuming that the patent utilization rate of an industry would be the same as its R&D utilization rate.[2]

Table 5 shows the estimated R&D utilization rates of "originating manufacturing industries", "manufacturing user industries", and "non-manufacturing user industries" which utilize R&D performed by originating manufacturing industries. The industries in each of these three categories were divided into three industry groups including high, intermediate, and low technology industry groups according to the ratio of the amount of R&D of originating manufacturing industries in each industry group exported to the manufacturing and non-manufacturing user industries in the same industry group to the total R&D of the originating industries.

The high technology industry group, including drugs (SIC 283), computers (SIC 357), and instruments (SIC 38) exports the highest percentage (70.8%) of its original total R&D to user industries, as shown in Table 5. The intermediate technology industry group, including chemicals (SIC 28), electrical and electronics (SIC 36), transportation (SIC 37), and aircraft and missiles (SIC 372), exports a lower percentage (58.3%) of its original R&D to user industries, and the low technology industry group including

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[2]This assumption is necessary, because the economic significance of an utilized patent can be measured mainly by the amount of R&D (as measured by R&D dollars) embodied in the products of industries which utilize the patent. Under this assumption, the number of utilized patents and utilization rates indicate the economic effect of utilized patents. Therefore, three patents utilized by one industry would have the same economic effect as one patent utilized by three industries.

TABLE 5

R&D UTILIZATION RATES BY INDUSTRY GROUP, 1974

Industry Group	Industries by SIC	Total R&D ($ million) Performed by Originating Manufacturing Industries	R&D ($ million) utilized by: Originating Manufacturing Industries (1) R&D	%	Manufacturing User Industries (2) R&D	%	Non-Manufacturing User Industries (3) R&D	%	Total (2) + (3) R&D	%
High Technology Industry Group	283	557.3	71.0	12.74 (0.50)	0.2	0.04 (0.00)	353.4	63.41 (2.49)	353.6	63.45 (2.49)
	357	1,153.0	110.5	9.58 (0.78)	286.6	24.86 (2.02)	604.1	52.39 (4.26)	890.7	77.25 (6.28)
	38	1,036.4	88.8	8.57 (0.63)	171.2	16.53 (1.21)	528.3	51.97 (3.73)	699.5	67.50 (4.94)
	Total	2,746.7	270.3	9.84 (1.91)	458.0	16.67 (3.23)	1,485.8	54.09 (10.48)	1,943.8	70.76 (13.71)
Intermediate Technology Industry Group	28	1,730.4	444.5	25.68 (3.14)	675.3	39.03 (4.76)	256.5	14.82 (1.81)	931.8	53.85 (6.57)
	36	2,364.5	561.7	23.76 (3.96)	231.2	9.78 (1.63)	974.2	41.20 (6.87)	1.205.4	50.98 (8.50)
	37	1,780.8	180.8	10.15 (1.28)	166.9	9.37 (1.18)	1,136.8	63.84 (8.02)	1,303.7	73.21 (9.20)
	372	659.4	160.5	24.34 (1.13)	3.4	0.51 (0.02)	367.6	55.75 (2.59)	371.0	56.26 (2.61)
	Total	6,535.1	1,347.5	20.62 (9.51)	1,076.8	16.48 (7.60)	2,735.1	41.85 (19.29)	3,811.9	58.33 (26.89)
Low Technology Industry Group	Total	4,893.9	1,877.3	38.36 (13.24)	934.0	19.08 (6.59)	1,418.6	28.99 (10.01)	2,352.6	48.07 (16.60)
All Industry Groups	Grand Total	14,175.7	3,495.1	24.83 (24.83)	2,468.8	17.42 (17.42)	5,639.5	39.78 (39.78)	8,108.3	57.20 (57.20)

Note: Two R&D utilization rates are given in this table. One is the percentage of utilized R&D to the total R&D performed by each originating manufacturing industry. The other is the percentage of utilized R&D to the grand total of R&D, as given in parentheses. The transportation industry (SIC 37) was included in the intermediate technology industry group because its original R&D was allocated almost exclusively (approximately 85%) to the development of motor vehicles and their components. Also, this table excludes the final consumption catagory in Scherer's (1982b) original matrix.

Source: Calculated from F. M. Scherer (1982b), "Inter-Industry Technology Flows in the United States", Research Policy, 11, Table 2, pp. 232-241.

other manufacturing industries (SIC 20 through SIC 27, SIC 35 except SIC 357, and SIC 39) exports the lowest percentage (48.1%) of its original R&D to other industries.[3]

This research, however, is concerned with the number of patents utilized by originating manufacturing industries and manufacturing user industries only. It was assumed that a patent is utilized as process technology when it is utilized by its originating industry. On the other hand, it was assumed to be utilized as product technology when it is produced by its originating industry in an industry group and utilized by all manufacturing user industries in other industry groups. Finally, it must be pointed out that Scherer's (1982b) matrix represents the interindustry R&D flows in 1974. Therefore, the use of patent utilization rates based on Scherer's matrix would result in a discrepancy between the actual and estimated number of utilized patents for different years.

Total Factor Productivity

Total factor productivity (TFP) is a measure of the physical relationship between output and total factor inputs, usually capital and labor. The total factor productivity with capital and labor inputs assumes technological substitutability between the factor inputs in the production process nd is measured geometrically by the parameter TP in the following multiplicative function which is known as a Cobb-Douglas production function (Kennedy and Thirlwall, 1972):

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[3]Despite the high rate of transportation (SIC 37) industry's R&D utilized by other user industries, the industry was classified in this study as an intermediate technology industry due to the fact that approximately 85 percent of its original R&D was performed for motor vehicles and components.

$$Q = TP \cdot L^{b} \cdot K^{(1-b)}, \qquad (1)$$

where Q is output, L is labor input, K is capital input, b is labor's share of output in the base year, and (1-b) is capital's share of output in the base year.

For the rate of change in total factor productivity (TPR), Equation (1) is modified into:

$$\Delta TP/TP = \Delta Q/Q - b(\Delta L/L) - (1-b)(\Delta K/K), \qquad (2)$$

Equation (2) expresses the rate of change in TFP as the difference between the rate of output change and a weighted sum of the rates of changes in factor inputs. In this study, the rate of change in TFP was employed as a measure of the rate of change in process technology under the conventional simplifying assumptions concerning the use of total factor productivity change.[4]

The Rate of Change in State Process Technology

State process technology was measured by the number of patents produced and utilized by all originating manufacturing industries in three industry groups (high, intermediate, and low technology industry groups) of each state (PTC_i), as estimated by the following equation:

$$PTC_i = PT_i^n \cdot \sum_{g=1}^{3} URC_g^n \cdot (E_{gi}^s / E_{gi}^n), \qquad (3)$$

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[4]Conventional simplifying assumptions on the use of TFP change include: 1) technological change is neutral, 2) capital and labor are substitutable for each other with a constant elasticity of substitution in a Cobb-Douglas production function, 3) factor markets are purely competitive, and 4) intangible factors such as labor and management skills and the quality of input materials do not affect the TFP change estimated with the quantity of labor and capital inputs (Kendrick, 1973).

where PT_i^n is the national total of patents for the year i,

URC_g^n is the national average patent utilization rate of the originating industries in the industry group g,[5] and

(E_{gi}^s/E_{gi}^n) is the state share of national total employment in the originating industries in the industry group g for the year i.[6]

For the rate of change in state process technology, two measures were employed. The first measure is the rate of change in state total factor productivity (TPR) in Equation (2). With specific output and factor inputs, TPR is expressed as :

$$TPR_{ij} = (\Delta DVA_{ij}/DVA_i) - b(\Delta L_{ij}/L_i) - (1-b)(\Delta DK_{ij}/DK_i), \qquad (4)$$

where $(\Delta DVA_{ij}/DVA_i)$ is the rate of change in the deflated state total of value-added in manufacturing between the initial year i and the terminal year j,

$(\Delta L_{ij}/L_i)$ is the rate of change in state total manufacturing employment for the same period,

$(\Delta DK_{ij}/DK_i)$ is the rate of change in the deflated state total of

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[5]State process technology was measured for all originating manufacturing industries in three industry groups rather than for the industries in each industry group in order to compare the rate of change in state process technology measured by the rate of change in the number of utilized patents with than measured by the rate of change in total factor productivity (TPR).

[6]In the case of process technology, a state's share of national total patents is better indicated by the share of national total of new capital expenditures than by the share of national total employment, because process technology is embodied in capital (Nelson, 1981, p. 1054). However, due to a substantial portion of suppressed data for new capital expenditures found in the <u>Annual Survey of Manufactures</u>, the state share of national total employment was used as a measure of the state share of national total patents.

capital assets, and

b is the ratio of the state total payroll to the deflated state total of value-added in manufacturing for the initial year i.

The data for value-added (VA), employment (L), capital assets (K), and payroll were drawn from the Annual Survey of Manufactures.[7] The values of VA and K were deflated by the Producer Price Indexes for industrial commodities as provided in the Statistical Abstract of the United States (U.S. Bureau of the Census, 1980).

The second measure is the rate of change in the total of patents utilized as process technology by all originating industries in three industry groups (PCR_{ij}), as estimated for each state by Equation (3):

$$PCR_{ij} = (\Delta PTC_{ij}/PTC_i), \qquad (5)$$

where ($\Delta PTC_{ij}/PTC_i$) is the rate of change in the number of patents produced and utilized as process technology by the originating industries in all three industry groups in each state between the initial year i and the terminal year j.

The Rate of Change in State Product Technology

State product technology was measured by the number of patents produced by the originating industries in an industry group g (e.g., the originating industry group g) and utilized as product technology by the manufac-

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[7]U.S. Bureau of the Census, Annual Survey of Manufactures for 1964-1965, 1968-1969, 1970-1971, 1975, 1975-1976, and 1978. The Annual Survey of Manufactures is the major source of data for this study. It provides value-added, manufacturing employment, and payroll data by state and by industry for each year and state total capital assets data for each year between 1969 and 1978 excluding 1972 and 1973.

turing user industries in other industry groups in each state ($PTDg_x$), as estimated by the following equation:[8]

$$PTDg_x = PT_x^n \cdot URD_r^n \cdot (E_{rx}^s/E_{rx}^n), \qquad (6)$$

where PT_x^n is the national total of patents for the year x,

URD_r^n is the national average patent utilization rate of the manufacturing user industries in all industry groups excluding the originating industry group g,[9] and

(E_{rx}^s/E_{rx}^n) is the state share of national total employment in the manufacturing user industries in all industry groups excluding the originating industry group g for the year x.

The national patent data were obtained by aggregating state patents provided by the U.S. Patent and Trademark Office (1977; 1982) as described in Chapter IV. In addition, state employment data for each user industry group were drawn from the Annual Survey of Manufactures.

Based on Equation (6), two measures of the rate of change in state product technology were developed. One is the rate of change in high and intermediate state product technology ($PDRH_{xy}$), which was measured by the rate of change in the number of patents produced by the high technology industry group and utilized by the intermediate and low technology industry groups plus the rate of change in the number of patents produced by

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[8]State patents were not used as a measure of state process technology due to the problem of tracing the interstate flows of the use of any patent.

[9]The 1974 national average R&D utilization rates in Table 5 were used as the patent utilization rates not only for 1974, but also for other years for which the numbers of utilized patents were estimated.

the intermediate technology industry group and utilized by the high and low technology industry groups:

$$PDRH_{xy} = (\Delta PTDH_{xy}/PTDH_{x}) + (\Delta PTDI_{xy}/PTDI_{x}), \qquad (7)$$

where $(\Delta PTDH_{xy}/PTDH_{x})$ is the rate of change in the number of patents produced by the high technology industry group and utilized by the intermediate and low technology industry groups for the period between the initial year x and the terminal year y, and

$(\Delta PTDI_{xy}/PTDI_{x})$ is the rate of change in the number of patents produced by the intermediate technology industry group and utilized by the high and low technology industry groups for the same period.

The other is the rate of change in low state product technology ($PDRL_{xy}$) as measured by the rate of change in the number of patentd produced by the low technology industry group and utilized by the high and intermediate technology industry groups:

$$PDRL_{xy} = (\Delta PTDL_{xy}/PTDL_{x}), \qquad (8)$$

where $(\Delta PTDL_{xy}/PTDL_{x})$ is the rate of change in the number of patents produced by the low technology industry group and utilized by the high and intermediate technology industry groups for the period between the initial year x and the terminal year y.

The Growth Rate of State Manufacturing Output

State manufacturing output was measured by the state total of value-added adjusted by Producer Price Indexes (DVA). The growth rate of state manufacturing output (VAR) was measured by:

$$VAR_{ij} = (\Delta DVA_{ij}/DVA_i), \tag{9}$$

where $(\Delta DVA_{ij}/DVA_i)$ is the rate of change in the deflated state total of value-added for the period between the initial year i and the terminal year j.

State Manufacturing Output Growth and the Changes in State Process and Product Technologies

The hypothesis which relates state manufacturing output growth to the changes in state process and product technologies was tested after 1) analyzing the regional patterns in the growth rate of state manufacturing output (VAR), in the rate of change in state process technology as measured by TPR and PCR, and also in the rate of change in state product technology as measured by PDRH and PDRL, and 2) determining the individual relationships between VAR and the rates of change in state process and product technologies. All of the empirical results are presented in Chapter VI.

The regional patterns in VAR for the 1971-1978 period (VAR7178) and in each of the other four variables (including TPR, PCR, PDRH, and PDRL) for the period for which each had the highest correlation with VAR7178 were analyzed in order to identify any distinctive patterns which may provide further evidence of shifting core-periphery relationships in the United States, as suggested by Norton and Rees (1979).

The individual relationships between VAR7178 and the rates of change in state process and product technologies were determined by the regression analyses of: 1) the correlations between VAR7178 and the two variables for the rate of change in state process technology (TPR and PCR, both separately and together) and the correlation between TPR and PCR (Figure 2, B), and 2) the correlations between VAR7178 and the two variables for the rate of change in state product technology (PDRH and PDRL, both separately and together) and the correlation between PDRH and PDRL (Figure 2, C). They were determined to compare TPR with PCR, PDRH with PDRL, and also TPR and PCR with PDRH and PDRL in the significance of their effects on VAR7178. In addition, residual analyses were performed in order to identify the states in which VAR7178 was poorly explained by each of the above four variables, by TPR and PCR together, and by PDRH and PDRL together.

The hypothesis was tested by multiple regression analyses of VAR7178 and the two combinations of the measures of the rates of change in state process and product technologies for the periods selected within the limitation of data availability (Figure 2, A):

$$VAR7178 = f\ (TPR_{ij},\ PDRH_{xy},\ PDRL_{xy}), \tag{10}$$

$$VAR7178 = f\ (PCR_{ij},\ PDRH_{xy},\ PDRL_{xy}), \tag{11}$$

where TPR_{ij} and PCR_{ij} are the two measures of the rate of change in state process technology as estimated by Equations (4) and (5), and

$PDRH_{xy}$ and $PDRL_{xy}$ are the two measures of the rate of change in state product technology as estimated by Equations (7) and (8).

Both the significance level of correlation coefficients and the explanatory power of the coefficients of multiple determination provided by the two series of multiple regressions were used as the criteria for accepting or rejecting the hypothesis. The results of multiple regressions were also used as the basis for determining the lags in the time of the peak

FIGURE 2

RESEARCH DESIGN

(A)

Research Goal

$VAR7178 = f\ (TPR_{ij},\ PDRH_{xy},\ PDRL_{xy})$

$VAR7178 = f\ (PCR_{ij},\ PDRH_{xy},\ PDRL_{xy})$

(B)

$VAR7178 = f\ (TPR_{ij},\ PCR_{ij})$

$VAR7178 = f\ (TPR_{ij})$

$VAR7178 = f\ (PCR_{ij})$

$TPR_{ij} = f\ (PCR_{ij})$

(C)

$VAR7178 = f\ (PDRH_{xy},\ PDRL_{xy})$

$VAR7178 = f\ (PDRH_{xy})$

$VAR7178 = f\ (PDRL_{xy})$

$PDRH_{xy} = f\ (PDRL_{xy})$

Regional Variations in State Patenting Activity and Its Intensity → Patent Utilization Rates of High, Intermediate, and Low Technology Industry Groups

Note: VAR7178 is the growth rate of state manufacturing output for the 1971-1978 period. TPR_{ij} and PCR_{ij} are the two measures of the rate of change in state process technology for the period between the year i and the year j. $PDRH_{xy}$ is the rate of change in high and intermediate state product technology for the period between the year x and the year y, and $PDRL_{xy}$ is the rate of change in low state product technology for the same period. The arrows indicate the sequence of this study.

impacts individual independent variables had on VAR7178. Finally, residual analyses were performed in order to determine the regional patterns in VAR7178 explained by each of the two sets of independent variables in the two best fit multiple regression equations. The empirical results are the focus of the following chapter.

CHAPTER VI

INTERSTATE VARIATIONS IN MANUFACTURING GROWTH AND DUAL EFFECTS OF TECHNOLOGICAL CHANGE

This chapter has three objectives. First, it analyzes the regional patterns in the growth rate of state manufacturing output for the 1971-1978 period (VAR7178) and in the rates of change in state process and product technologies (as measured by TPR, PCR, PDRH, and PDRL, separately) for selected periods. Second, it determines the individual relationships between VAR7178 and the rates of change in state process and product technologies. Third, it tests the hypothesis concerning the dual effects of the rates of change in state process and product technologies on VAR7178 by using the methods outlined in Chapter V.

Interstate Variations in Manufacturing Output Growth

It has been suggested that two important structural changes have been taking place in the economic system of the United States since the early 1970s. First, an increasing dominance by non-manufacturing activities has evolved over manufacturing activities (Moriarty, 1976). Second, a rapid growth of high technology industries within the manufacturing sector itself has taken place (Rees, 1979).

The regional implications of such changes have been identified mainly in terms of the process of core-periphery realignment, or interregional shifts in manufacturing in the United States, which can be explained by

Vernon's (1966) product life cycle model. It implies that the Manufacturing Belt (or the core regions including the New England, the Middle Atlantic, and the East North Central Census Regions), which has traditionally acted as a "seed-bed" for technological innovation, has been losing manufacturing workers to the periphery regions in the American South and West (Norton and Rees, 1979).[1] Interregional shifts in manufacturing as explained within the framework of product life cycle are concerned with the shifts in manufacturing employment only. This section presents and describes the interstate variations in the growth rate of manufacturing output for the 1971-1978 period,[2] which may explain the interregional shifts in another aspect of manufacturing activities.

Map 4 presents the three basic regional patterns of the growth rate of state manufacturing output for the 1971-1978 period (VAR7178). First, only five of the fourteen states in the Manufacturing Belt experienced positive growth of over 12.5 percent. In addition, New York and New Jersey experienced negative growth. Second, most states in the Sun Belt experi-

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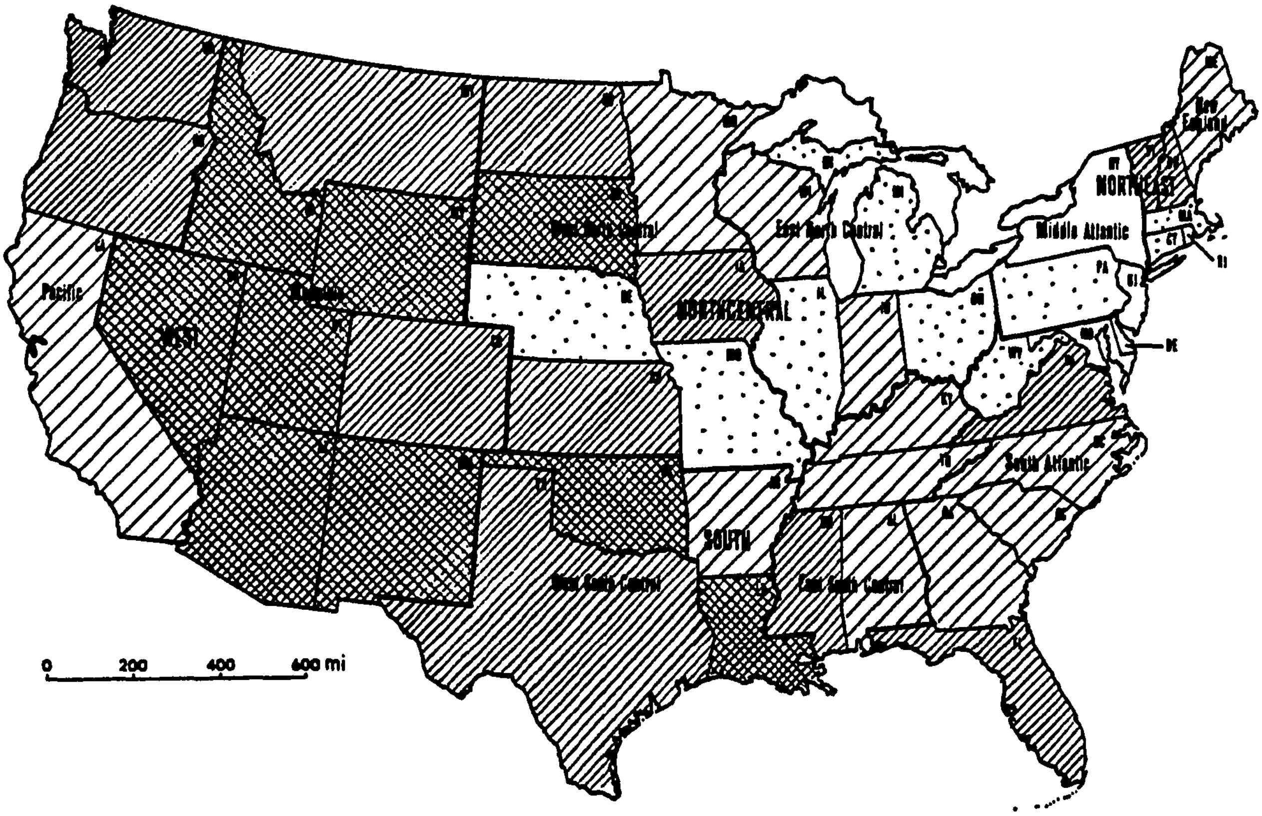
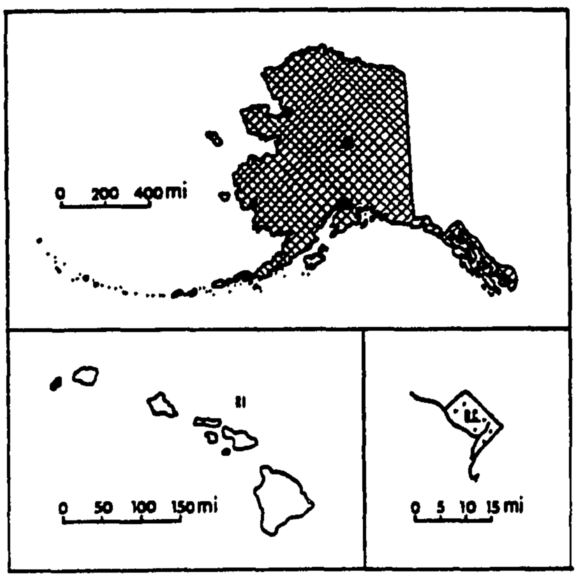
[1]The U.S. Bureau of the Census divides the United States into nine Census Regions including the New England, the Middle Atlantic, the East North Central, the West North Central, the South Atlantic, the East South Central, the West South Central, the Mountain, and the Pacific Regions, as shown in Map 4. The three regions in the Northeast including the New England, the Middle Atlantic, and the East North Central Regions are called the "Manufacturing Belt" or core regions, while other regions are called periphery regions. Of the periphery regions, the South Atlantic, the East South Central, and the West South Central Regions are called the "Sun Belt" (Norton and Rees, 1979; Rees, 1979).

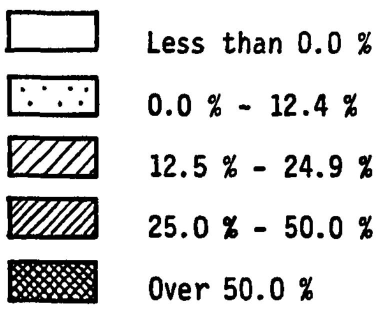
[2]In this study, the growth rate of state manufacturing output was measured for the 1971-1978 period only, becacse the initial year (1971) of the period indicates roughly the beginning of the major change in core-periphery relationships (Rees, 1979, p. 45) and the terminal year (1978) is the last year for which the data on state manufacturing output were available in the <u>Annual Survey of Manufactures</u> at the time of this study.

MAP 4

PERCENTAGE CHANGE IN STATE MANUFACTURING OUTPUT, 1971 - 1978 (VAR7178)







Source: Table 6.

enced positive growth of over 12.5 percent. Exceptions are Delaware and Maryland with negative growth rates and West Virginia with a positive growth rate of less than 12.5 percent. All these states are "border" states with a considerable amount of long-standing industry. Third, most states in the West and the West North Central Region experienced positive growth of over 25.0 percent. Four states are exceptions. They are California (23.6%), Minnesota (23.1%), Nabraska (11.1%), and Missouri (8.8%).

The regional patterns of variation in VAR7178 roughly correspond to those of the shifts in manufacturing employment as identified by Norton and Rees (1979, pp. 142-144). However, they are less distinctive than those of the shifts in manufacturing employment due to the positive growth experienced by nearly all states in the Manufacturing Belt (except New York and New Jersey) and also due to the growth rates of most states in the Sun Belt which are generally lower than those of most states in the West, as shown in Table 6.

The lower growth rates of most states in the Sun Belt are attributable to the fact that, with the same amount of increase in output, a state with a larger absolute output in 1971 tends to grow less fast than a state with a smaller output at the beginning of the period. However, the growth rates of over 25.0 percent in Oklahoma, Texas, and Louisiana in the Sun Belt are attributable to the growth of their energy industry after the 1974 oil embargo.

Changes in State Process Technology and Manufacturing Output Growth

Regional variations in manufacturing output growth have been explained traditionally by variations in the rate of change in state process tech-

TABLE 6

THE GROWTH RATE OF STATE MANUFACTURING OUTPUT, 1971 - 1978

STATE	DVA71	DVA78	VAR7178
AL	3,971.0	4,654.2	17.2
AK	173.3	261.1	50.7
AZ	1,213.5	1,890.9	55.8
AR	2,120.9	2,627.5	23.9
CA	24,161.4	29,852.1	23.6
CO	1,830.4	2,501.3	36.7
CT	5,301.7	5,869.5	10.7
DE	1,122.7	960.6	-14.4
DC	307.0	319.1	3.9
FL	4,225.9	5,380.2	27.3
GA	5,725.9	6,659.3	16.3
HI	381.2	373.9	-1.9
ID	586.3	880.4	50.2
IL	19,973.5	21,420.4	7.2
IN	10,581.9	12,273.1	16.0
IA	3,454.1	4,702.1	36.1
KS	2,244.2	2,938.8	31.0
KY	4,529.5	5,179.1	14.3
LA	3,071.4	4,802.5	56.4
ME	1,059.0	1,285.1	21.4
MD	3,750.6	3,695.9	-1.5
MA	8,321.3	8,897.8	6.9
MI	17,765.6	19,964.0	12.4
MN	4,230.7	5,209.2	23.1
MS	1,960.7	2,858.9	45.8
MO	6,595.2	7,178.3	8.8
MT	289.6	406.2	40.3
NE	1,397.1	1,551.9	11.1
NV	127.9	315.2	146.5
NH	954.2	1,320.1	38.3
NJ	12,615.1	11,807.7	-6.4
NM	239.2	379.6	58.7
NY	25,295.5	23,070.6	-8.8
NC	8,610.2	9,845.6	14.3
ND	165.6	231.7	39.9
OH	21,026.9	22,751.4	8.2
OK	1,607.7	2,501.1	55.6
OR	2,459.8	3,422.4	39.1
PA	19,249.8	19,365.1	0.6
RI	1,287.4	1,431.7	11.2
SC	3,711.2	4,525.7	21.9
SD	198.2	346.8	74.9
TN	5,897.4	6,707.6	13.7
TX	12,089.3	17,429.0	44.2
UT	757.4	1,136.7	50.1
VT	492.6	660.3	34.0
VA	4,533.6	5,712.1	26.0
WA	3,608.2	4,987.3	38.0
WV	2,092.6	2,114.0	1.0
WI	7,428.9	8,984.7	20.9
WY	104.6	203.2	94.2

Note: DVA is the state total of value-added (in million dollars) for 1971 adjusted by Producer Price Indexes for industrial commodities. VAR7178 is the growth rate of state manufacturing output as measured by the rate of change in state total of value-added (in million dollars) for the 1971-1978 period.

Sources: U.S. Bureau of the Census, Annual Survey of Manufactures: 1971-1972 (Washington, D.C.: U.S. Government Printing Office, 1973); and U.S. Bureau of the Census, Annual Survey of Manufactures: 1978 (Washington, D.C.: U.S. Government Printing Office, 1981).

nology, as indicated by productivity growth (Sveikauskas, 1981; Casetti, 1982). This section presents the interstate variations in the two measures of the rate of change in state process technology (TPR and PCR) and examines their correlation with state manufacturing output growth (VAR7178).

Interstate Variations in the Rates of Change in State Process Technology

It has been suggested that labor productivity increases fast in the states that experience a rapid growth in population and manufacturing output (Casetti, 1982). This implies that productivity growth would be much higher in the periphery regions than in the core regions due to the shifts of population and manufacturing activities from the core to the periphery regions (Norton and Rees, 1979).

The analysis of the interstate variations in the rate of change in state total factor productivity for the 1971-1978 period (TPR7178) indicates no clear pattern of shifting core-periphery relationships in TPR.[3] Surprisingly, eight of the fourteen states in the Manufacturing Belt experienced productivity growth of over 12.5 percent (Map 5). At the same time, only five of the seventeen states in the Sun Belt and only nine of the twenty states in the West and the West North Central Region experienced growth of over 12.5 percent. These changes in productivity are made up of changes in capital and labor inputs, and these appear to vary regionally. In the Manufacturing Belt, the growth of TPR7178 generally results from an increase in labor inputs and a decrease in capital inputs. In the South and West,

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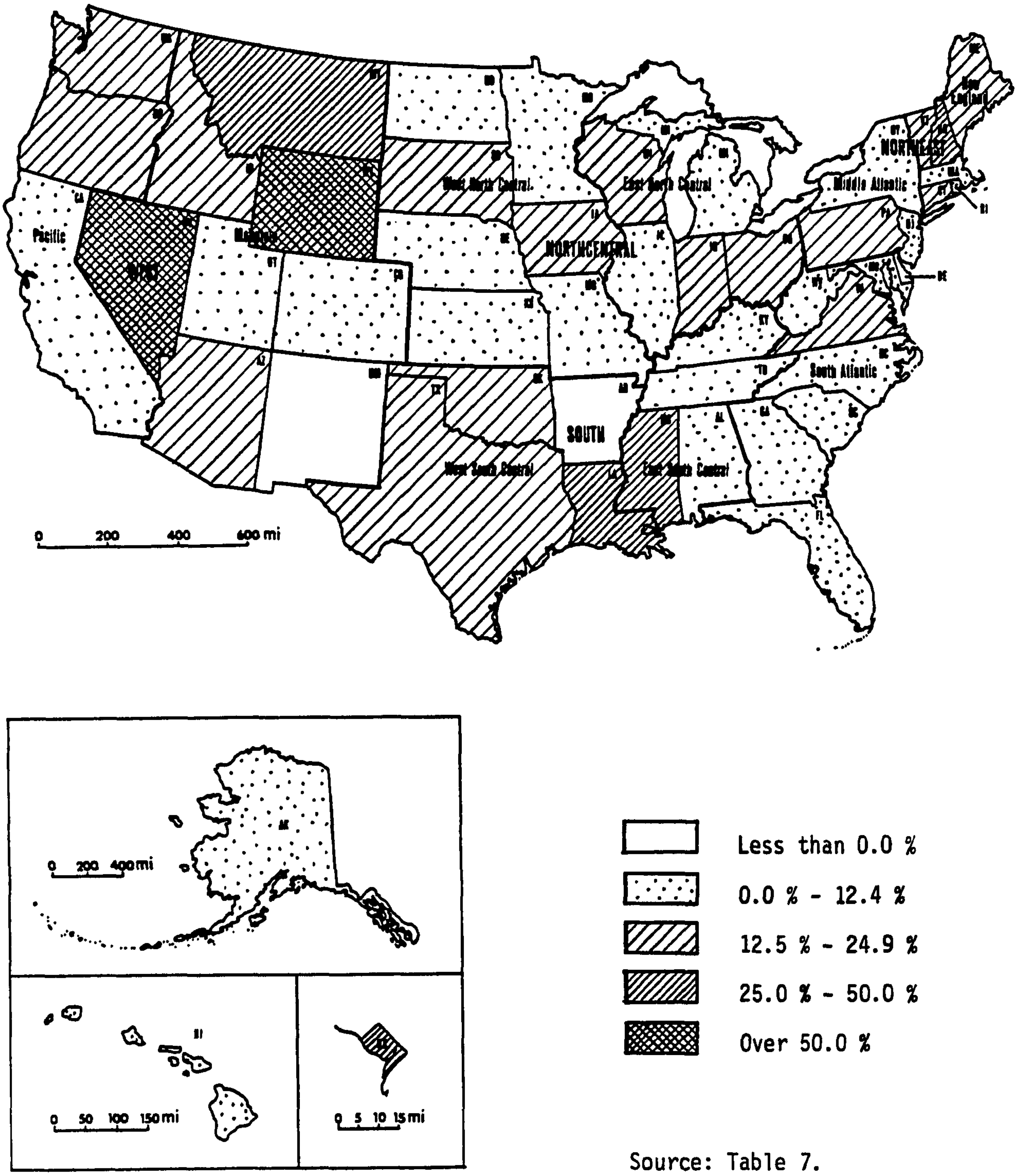
[3]The regional patterns of the interstate variations in TPR and PCR were analyzed for the 1971-1978 and the 1969-1976 periods, respectively, for which the two variables show the highest correlations with VAR7178. The complete results of this lag analysis are presented in Table 8.

MAP 5

PERCENTAGE CHANGE IN STATE TOTAL FACTOR PRODUCTIVITY, 1971 - 1978 (TPR7178)



Source: Table 7.

productivity growth tends to be due to an increase in both labor and capital, as shown in Table 7. This suggests a flow of both capital and process technology embodied in capital from the Manufacturing Belt to other regions of the country.

Core-periphery shifts are more evident from interstate variations in the rate of change in the estimated number of patents utilized as process technology for the 1969-1976 period (PCR6976), as shown in Map 6. All states in the Manufacturing Belt (except Vermont, New Hampshire, Rhode Island, and Wisconsin) suffered a decline in PCR6976, while only nine states in the periphery regions experienced a decline in PCR6976. As in the case of VAR-7178, the states with smaller numbers of patents utilized as process technology in 1969 generally show higher growth rates for the 1969-1976 period than the states with larger numbers of patents, as shown in Table 7. This explains the growth rates of over 12.5 percent in most states in the Mountain and West North Central Regions.

The Effects of Rates of Change in State Process Technology on State Manufacturing Output Growth

Two measures of the rate of change in state process technology have been used in this study: the rate of change in total factor productivity (TPR), and the rate of change in the estimated number of patents utilized as process technology (PCR). In this section, these two measures are correlated with the growth rate of state manufacturing output (VAR), at least in part to compare their relationships with VAR. The comparative analyses of VAR7178, TPR7178, and PCR6976 suggest that the distribution of VAR7178 is more closely related to that of the utilized patent measure (PCR6976) than to that of the traditional measure of productivity growth (TPR7178).

TABLE 7

RATE OF CHANGE IN STATE PROCESS TECHNOLOGY AND ITS COMPONENTS

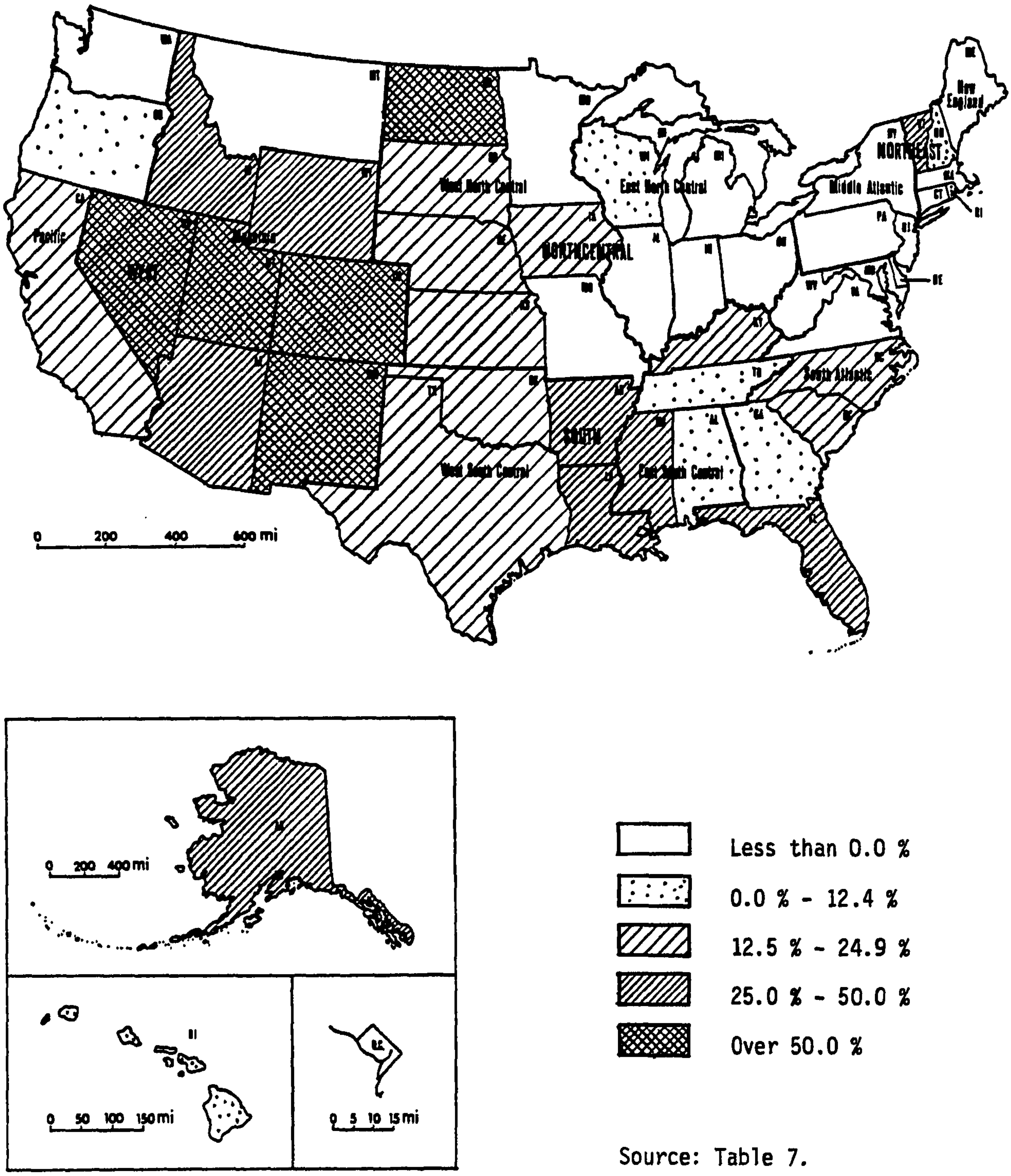
STATE	LR7178	DKR7178	TPR7178	PTC69	PTC76	PCR6976
AL	16.0	16.3	1.1	175.0	195.2	11.6
AK	39.0	47.2	6.9	2.3	3.3	44.1
AZ	49.2	25.5	18.0	56.8	74.1	30.4
AR	24.5	28.7	-3.1	88.9	113.0	27.1
CA	31.5	-6.5	11.0	1,051.3	1,204.1	14.5
CO	39.4	25.4	4.1	57.4	87.2	51.8
CT	6.2	-23.6	16.5	350.5	300.1	-14.4
DE	-4.0	-16.1	-5.2	18.4	16.2	-11.6
DC	-13.2	-39.8	28.5	9.9	8.0	-19.5
FL	28.5	7.3	10.0	190.0	237.7	25.1
GA	18.0	11.8	1.8	264.0	272.6	3.3
HI	-2.9	-16.9	9.2	10.4	10.7	2.5
ID	30.2	24.9	22.8	18.4	26.6	44.3
IL	2.2	-12.7	12.3	899.8	794.8	-11.7
IN	10.5	-14.9	18.3	503.6	500.4	-0.7
IA	22.8	12.8	18.9	125.7	145.1	15.5
KS	49.9	9.1	5.6	91.7	112.6	22.8
KY	19.0	1.3	6.7	151.2	177.0	17.1
LA	24.7	24.3	31.9	105.0	135.5	29.1
ME	12.4	1.7	14.2	53.7	46.0	-14.4
MD	-0.7	-24.0	10.7	187.6	160.9	-14.2
MA	3.9	-12.0	10.4	453.3	407.7	-10.1
MI	14.1	-10.6	9.4	776.8	753.0	-3.1
MN	31.7	0.8	6.5	211.1	190.0	-10.0
MS	22.0	8.3	30.9	105.9	142.3	34.3
MO	3.9	-7.5	10.8	285.6	272.6	-4.5
MT	27.1	4.1	25.1	8.4	8.2	-2.3
NE	15.3	3.6	2.9	48.8	56.9	16.5
NV	134.7	17.1	77.4	3.4	7.3	113.9
NH	26.9	-5.0	26.5	58.0	58.8	1.3
NJ	0.2	-19.5	3.2	594.8	480.9	-19.1
NM	23.8	110.8	-6.9	9.9	19.0	92.5
NY	-9.7	-20.3	5.9	1,249.0	939.3	-24.8
NC	12.9	2.4	7.4	377.4	424.9	12.6
ND	39.6	28.8	7.1	3.6	6.5	81.7
OH	2.3	-21.1	17.1	919.7	847.1	-7.9
OK	30.5	38.1	21.7	72.2	81.7	13.1
OR	31.3	1.5	22.7	98.0	98.2	0.2
PA	-5.3	-23.0	14.1	950.3	800.0	-15.8
RI	17.1	-4.7	4.7	70.1	71.0	1.3
SC	19.3	1.5	11.9	193.2	219.1	13.4
SD	48.4	73.5	14.6	7.8	9.1	17.4
TN	14.8	0.1	7.2	281.4	311.9	10.8
TX	38.4	17.5	18.0	447.4	532.3	19.0
UT	61.2	25.1	8.6	23.1	36.1	56.6
VT	20.3	10.1	18.6	13.0	17.7	36.6
VA	15.9	4.9	15.9	229.7	217.5	-5.3
WA	29.6	-0.3	23.3	181.1	166.4	-8.1
WV	4.7	-20.2	10.6	75.9	74.9	-1.3
WI	17.1	-0.4	12.6	318.4	325.4	2.2
WY	34.4	37.0	58.3	1.9	2.7	40.0

Note: LR7178 is the rate of change in state total manufacturing employment for the 1971-1978 period, DKR7178 is the rate of change in the adjusted state total of capital assets in million dollars, TPR7178 is the rate of change in state total factor productivity, PTC69 is the estimated number of patents utilized as process technology in each state in 1969, and PCR6976 is the rate of change in the estimated number of patents utilized as process technology for the 1969-1976 period.

Sources: U. S. Department of Commerce, Patent and Trademark Office, Technology Assessment and Forecast: 7th Report. (Washington, D. C.: U. S. Government Printing Office, 1977); U. S. Department of Commerce, Bureau of the Census, Annual Survey of Manufactures: 1971-1972. (Washington, D. C.: U. S. Government Printing Office, 1973); and U. S. Department of Commerce, Bureau of the Census, Annual Survey of Manufactures: 1978. (Washington, D. C.: U. S. Government Printing Office, 1981).

MAP 6

PERCENTAGE CHANGE IN THE NUMBER OF PATENTS UTILIZED AS STATE PROCESS TECHNOLOGY, 1969 - 1976 (PCR6976)



Source: Table 7.

Table 8 provides results of regression analyses of VAR7178 on TPR and PCR, both separately and together, including an analysis of the lagged effect of technological change on state manufacturing output growth.

The results of the first three regressions in the table address the lagged effect, and relate VAR7178 to TPR for three consecutive seven-year periods between 1969 and 1978.[4] These indicate significant correlations between VAR7178 and TPR for two of the three periods. The relationship between VAR7178 and TPR is the most significant for the 1971-1978 period for TPR, which suggests that the rate of change in state process technology as measured by TPR has its peak impact on VAR7178 for the same period in a zero-lag relationship.

TPR7178 explains 50.0 percent of total variation in VAR7178, as shown in Table 8. It also explains VAR7178 well in most states in the Manufacturing and Sun Belts. However, it overpredicts manufacturing output growth in eight states (Connecticut, New York, Pennsylvania, Ohio, Washington, D.C., Maryland, West Virginia, and Hawaii) and underpredicts it in nine states (North Dakota, South Dakota, Colorado, New Mexico, Utah, Arizona, Arkansas, and Alaska).

The correlation between VAR7178 and TPR7178, however, is less significant than that between VAR7178 and PCR6976, as shown in Table 8. The R^2 value of PCR6976 (0.585) is higher than for VAR7178 on TPR7178 (0.500). The correlation is also much more significant between VAR7178 and PCR6976 than between VAR7178 and PCR7177 or PCR7178, indicating a two-year lag in

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[4]In this study, the individual effects on VAR7178 of TPR, PCR, PDRH, and PDRL were determined for three consecutive seven-year periods, including 1969-1976, 1970-1977, and 1971-1978, in order to make the seven-year interval in the three periods consistent with the interval in the period for VAR7178.

TABLE 8

THE GROWTH RATE OF STATE MANUFACTURING OUTPUT AND THE RATE OF CHANGE IN STATE PROCESS TECHNOLOGY

Regression Equation and Model	Dependent Variable	Constant (a)	Coef- ficient (b)	Inde- pendent Variable	Coef- ficient (c)	Inde- pendent Variable	R^2
1 A	VAR7178	25.72	0.33 (1.40)	TPR6976			0.039
2 A	VAR7178	15.03	0.97* (3.76)	TPR7077			0.224
3 A	VAR7178	8.13	1.40* (7.00)	TPR7178			0.500
1 B	VAR7178	18.12	0.74* (8.30)	PCR6976			0.585
2 B	VAR7178	29.87	0.77* (3.89)	PCR7077			0.236
3 B	VAR7178	38.65	0.77* (4.21)	PCR7178			0.265
1 C	TPR6976	8.25	-0.01 (0.16)	PCR6976			0.001
2 C	TPR7077	12.76	0.07 (1.04)	PCR6976			0.022
3 C	TPR7077	13.78	0.03 (0.30)	PCR7077			0.002
4 C	TPR7178	12.45	0.14** (2.16)	PCR6976			0.087
5 C	TPR7178	14.64	0.10 (0.89)	PCR7077			0.016
6 C	TPR7178	16.57	0.16 (1.51)	PCR7178			0.044
1 D	VAR7178	15.21	0.75* (8.77)	PCR6976	0.35** (2.44)	TPR6976	0.630
2 D	VAR7178	27.21	0.78* (3.97)	PCR7077	0.33 (1.63)	TPR6976	0.276
3 D	VAR7178	35.87	0.79 (4.45)	PCR7178	0.38*** (1.95)	TPR6976	0.319
4 D	VAR7178	8.48	0.69* (9.16)	PCR6976	0.76* (4.75)	TPR7077	0.717
5 D	VAR7178	17.04	0.74* (4.33)	PCR7077	0.93* (4.20)	TPR7077	0.442
6 D	VAR7178	25.38	0.76* (4.93)	PCR7178	0.96* (4.52)	TPR7077	0.485
7 D	VAR7178	6.12	0.59* (10.02)	PCR6976	1.04* (8.68)	TPR7178	0.838
8 D	VAR7178	10.85	0.64* (4.75)	PCR7077	1.30* (7.73)	TPR7178	0.660
9 D	VAR7178	18.10	0.57* (4.33)	PCR7178	1.24* (7.07)	TPR7178	0.640

Note: t-values are given in parentheses. * indicates significance at the 0.001 level, ** at the 0.05 level, and *** at the 0.10 level.

Sources: Regressions are of the form: (A) VAR7178 = a + b(TPR), (B) VAR7178 = a + b(PCR), (C) TPR = a + b(PCR), and (D) VAR7178 = a + b(PCR) + c(TPR).

the time of the peak impact of PCR on VAR7178.[5]

PCR6976 explains VAR7178 in most states in the Manufacturing and Sun Belts. However, it overpredicts VAR7178 in six states (Delaware, North Dakota, Nebraska, New Mexico, Colorado, and Hawaii) and underpredicts it in eight states (New Hampshire, Oklahoma, South Dakota, Montana, Wyoming, Nevada, Washington, D.C., and Oregon). This also suggests that PCR6976 is a somewhat better indicator of the interstate variations in VAR7178.

Multiple regression analyses of VAR7178 on TPR and PCR indicate that the combined effects of TPR and PCR are generally much more significant than their individual effects on VAR7178, as shown in Table 8. Most correlation coefficients of TPR and PCR are significant and the R^2 s exceed 0.600 in five of the nine multiple regressions (Equations 1D, 4D, 7D, 8D, and 9D in Table 8). Both variables have positive signs, indicating that each contributes, but differently, to explaining the process innovation component of variations in the growth rate of manufacturing output.

The results of the multiple regressions also indicate the relative importance of TPR7178 and PCR6976 over TPR and PCR for other periods.[6] They explain the largest portion of total variation in VAR7178 (R^2: 0.838). They also explain VAR7178 well in most states in all regions. Exceptions are Arkansas, Arizona, Minnesota, Oklahoma, South Dakota, and Washington where VAR7178 is underpredicted, and Washington, D.C., Hawaii, Mississippi,

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[5]The lag in the time of the peak impact of PCR on VAR7178 may be more than two years. Due to the lack of employment data for high, intermediate, and low technology industries for 1968 and the previous years, the impacts of PCR for other periods were not tested in this study.

[6]The highly significant multiple correlations between VAR7178 and TPR7178 and PCR6976 are especially significant, given the weak correlation between TPR7178 and PCR6976, as shown in Table 9.

TABLE 9

SIMPLE CORRELATION COEFFICIENTS

	TPR6976	TPR7077	TPR7178	PCR6976	PCR7077	PCR7178
VAR7178	0.197	0.473	0.707	0.765	0.486	0.515
TPR6976	1.000	0.540	0.353	-0.022	-0.005	-0.068
TPR7077	0.540	1.000	0.739	0.147	0.042	0.010
TPR7178	0.353	0.739	1.000	0.295	0.126	0.210
PCR6976	-0.022	0.147	0.295	1.000	0.559	0.515
PCR7077	-0.005	0.042	0.126	0.559	1.000	0.950
PCR7178	-0.068	0.010	0.210	0.515	0.950	1.000
PDRL6976	-0.184	-0.075	0.097	0.547	0.541	0.511
PDRL7077	-0.102	-0.119	0.012	0.139	0.604	0.618
PDRL7178	-0.097	-0.123	0.021	0.147	0.613	0.639
PDRH6976	-0.039	0.159	0.312	0.962	0.533	0.517
PDRH7077	0.030	0.054	0.137	0.448	0.757	0.751
PDRH7178	-0.016	0.056	0.272	0.433	0.734	0.813

	PDRL6976	PDRL7077	PDRL7178	PDRH6976	PDRH7077	PDRH7178
VAR7178	0.249	0.038	0.060	0.803	0.493	0.538
TPR6976	-0.184	-0.102	-0.097	-0.039	0.030	-0.016
TPR7077	-0.075	-0.119	-0.123	0.159	0.054	0.056
TPR7178	0.097	0.012	0.021	0.312	0.137	0.272
PCR6976	0.547	0.139	0.147	0.962	0.448	0.433
PCR7077	0.541	0.604	0.613	0.533	0.757	0.734
PCR7178	0.511	0.618	0.639	0.517	0.751	0.813
PDRL6976	1.000	0.635	0.623	0.378	0.119	0.172
PDRL7077	0.635	1.000	0.998	0.099	0.115	0.192
PDRL7178	0.623	0.998	1.000	0.114	0.127	0.208
PDRH6976	0.378	0.099	0.114	1.000	0.518	0.499
PDRH7077	0.119	0.115	0.127	0.518	1.000	0.947
PDRH7178	0.172	0.192	0.208	0.499	0.947	1.000

Note: VAR7178 is the growth rate of state manufacturing output for the 1971-1978 period. TPR_{ij} is the rate of change in state total factor productivity for the period between the year i and the year j. PCR_{ij} is the rate of change in the estimated number of patents utilized as process technology by all originating manufacturing industries. $PDRH_{xy}$ is the rate of change in high and intermediate state product technology for the period between the year x and the year y. $PDRL_{xy}$ is the rate of change in low state product technology.

North Dakota, Vermont, and West Virginia where VAR7178 is overpredicted. All major industrial states are accounted for by the combination of TPR-7178 and PCR6976.

Changes in State Product Technology and Manufacturing Output Growth

The importance of product technology for economic growth has been emphasized only in recent years (Thomas, 1975; Malecki, 1983b). This section presents the interstate variations in the rates of change in two measures of state product technology: the combined rates of change in high and intermediate state product technologies (PDRH), and the rate of change in low state product technology (PDRL),[7] and attempts to account for variations in VAR7178 by PDRH and PDRL.

Interstate Variations in the Rates of Change in State Product Technology

The analysis of interstate variations in PDRH for the 1969-1976 period (PDRH6976) reveals a clear pattern with a sharp distinction between core regions in the Manufacturing Belt and the periphery regions, as shown in Map 7. Only two states in the Manufacturing Belt (Vermont and Wisconsin) experienced growth in PDRH6976, while nearly all states in the periphery regions (except Montana, Missouri, Minnesota, West Virginia, Maryland, Washington, D.C., and Delaware) experienced growth in PDRH6976. Generally, the growth rates are higher for small states than for larger states, as shown in Table 10. The decrease of PDRH in most states in the Manufactur-

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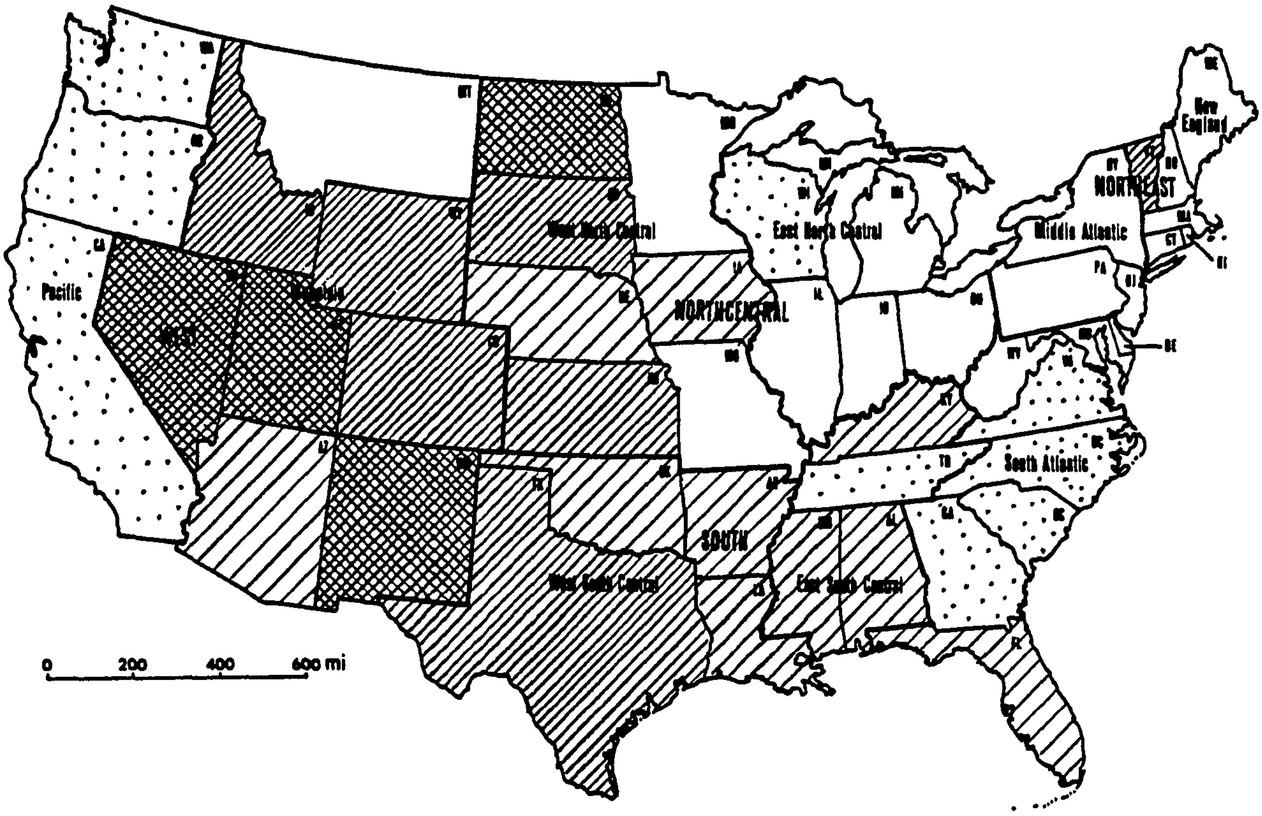
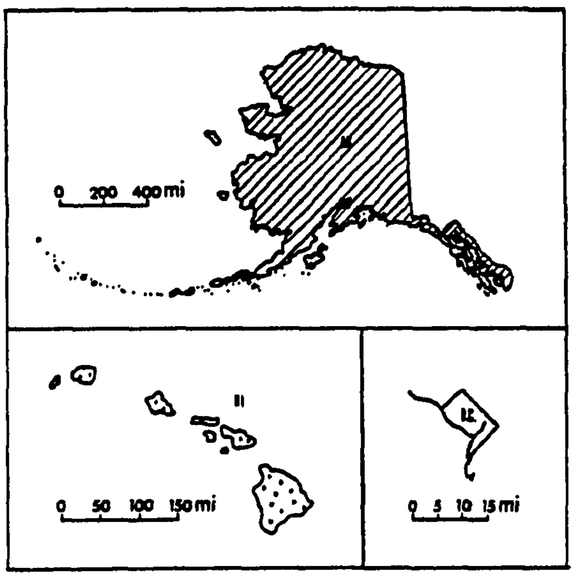
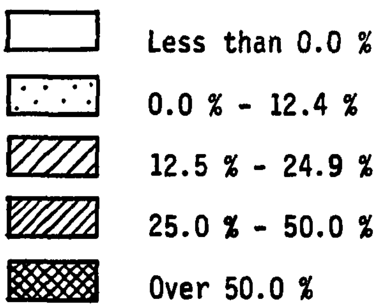
[7]The interstate variations in PDRH and PDRL were analyzed for the 1969-1976 period only, for which both variables show the highest correlations with VAR7178. For the calculation of PDRH and PDRL, see Chapter V.

MAP 7

PERCENTAGE CHANGE IN HIGH AND INTERMEDIATE
STATE PRODUCT TECHNOLOGY, 1969 - 1976 (PDRH6976)







Source: Table 10.

TABLE 10

RATE OF CHANGE IN STATE PRODUCT TECHNOLOGY AND ITS COMPONENTS
1969 - 1976

STATE	PTDH69	PTDH76	PDRH6976	PTDL69	PTDL76	PDRL6976
AL	97.3	109.4	12.5	29.1	29.4	1.2
AK	1.7	2.3	38.7	0.0	0.1	0.0
AZ	21.3	25.6	20.4	19.3	26.0	34.8
AR	49.2	58.3	18.7	15.1	21.2	40.9
CA	386.0	424.6	10.0	355.2	422.7	19.0
CO	30.7	39.8	29.6	10.0	23.5	136.3
CT	116.3	101.9	-12.4	125.1	109.5	-12.5
DE	11.4	8.1	-29.1	1.6	3.3	106.7
DC	7.2	5.6	-21.9	0.0	0.1	0.0
FL	83.0	94.7	14.1	52.4	72.0	37.3
GA	140.0	150.0	7.1	50.0	43.0	-13.9
HI	7.6	7.8	2.0	0.0	0.0	0.0
ID	11.1	15.6	39.6	2.2	3.3	52.0
IL	395.7	360.7	-8.8	235.0	204.8	-12.9
IN	193.3	186.0	-3.8	162.0	162.2	0.1
IA	63.9	73.4	14.9	26.2	29.0	10.9
KS	32.1	42.2	31.5	33.2	35.4	6.8
KY	68.2	81.8	19.9	39.4	42.4	7.7
LA	45.4	52.4	15.5	29.7	41.2	38.9
ME	35.3	32.7	-7.4	3.8	0.8	-79.9
MD	80.2	69.9	-12.8	53.6	42.5	-20.7
MA	199.8	168.3	-15.8	117.3	124.6	6.2
MI	277.1	251.2	-9.4	272.8	268.5	-1.6
MN	94.7	89.3	-5.8	49.0	48.6	-0.7
MS	53.8	62.7	16.7	22.0	36.6	66.6
MO	113.2	104.6	-7.6	89.0	84.4	-5.2
MT	5.9	5.6	-4.7	0.3	0.3	34.6
NE	22.4	27.5	23.1	12.1	13.0	7.7
NV	1.9	3.9	107.2	0.6	1.3	115.3
NH	28.9	27.9	-3.3	12.7	14.2	12.1
NJ	230.5	191.0	-17.1	182.5	151.4	-17.1
NM	5.0	9.2	82.2	2.0	4.2	108.4
NY	535.5	411.5	-23.2	327.0	264.0	-19.3
NC	227.2	245.6	8.1	45.2	57.7	27.7
ND	2.6	4.7	80.7	0.0	0.0	0.0
OH	403.8	363.3	-10.0	251.4	230.5	-8.3
OK	35.3	43.5	23.2	16.5	14.1	-14.3
OR	54.7	56.4	3.2	15.6	15.4	-1.2
PA	461.7	398.4	-13.7	209.4	172.4	-17.7
RI	39.8	38.8	-2.4	9.9	12.2	23.1
SC	108.0	117.7	8.9	31.0	37.8	21.8
SD	4.9	6.6	36.4	0.8	0.0	-100.0
TN	131.1	143.4	9.4	69.7	75.4	8.1
TX	188.9	242.5	28.4	131.4	131.1	-0.2
UT	11.3	17.6	56.0	5.3	7.8	47.0
VT	9.1	11.9	30.7	0.3	1.0	223.0
VA	101.1	108.2	7.1	63.0	44.5	-29.3
WA	63.4	68.0	7.2	65.6	47.6	-27.4
WV	34.9	33.4	-4.3	19.3	18.9	-2.4
WI	155.9	159.5	2.3	71.0	70.4	-0.8
WY	1.4	2.0	39.2	0.0	0.0	0.0

Note: PTDH69 is the estimated number of patents produced by high and intermediate technology industry groups and utilized as product technology by manufacturing user industries in 1969, PDRH6976 is the rate of change in PTDH for the 1969-1976 period, PTDL69 is the estimated number of patents produced by low technology industry group and utilized as product technology by manufacturing user industries in 1969, and PDRL6976 is the rate of change in PTDL for the 1969-1976 period.

Sources: U. S. Department of Commerce, Patent and Trademark Office, Technology Assessment and Forecast: 7th Report. (Washington, D. C.: U. S. Government Printing Office, 1977), pp. 187-195.

ing Belt and the increase in most states in the periphery regions indicate the decentralization of high and intermediate technology industries at the innovation phase of product life cycle from the core regions to periphery regions (Norton and Rees, 1979, p. 149).

The analysis of interstate variations in PDRL for the 1969-1976 period (PDRL6976) also indicates the patterns of shifting core-periphery relationships, as shown in Map 8. However, the patterns are less distinctive than those of interstate variations in PDRH6976. In the core regions of the Manufacturing Belt, five states experienced positive growth in PDRL6976. Surprisingly, four of them are New England states including Vermont, New Hampshire, Massachusetts, and Rhode Island (Map 8). In the periphery regions, all but eleven states experienced a positive growth,[8] which also indicates the decentralization of low technology industries from the core regions to the periphery regions. However, the high growth rates of over 25.0 percent in PDRL in all states in the Mountain Region (except Wyoming) is attributable to the small numbers of their patents utilized as low state product technology in 1969, as shown in Table 10.

The Effects of Rates of Change in State Product Technology on State Manufacturing Output Growth

The patterns in the distribution of PDRH6976 are similar to those of PCR6976 (Maps 6 and 7). However, the results of regression analyses indicate a more significant correlation between VAR7178 and PDRH6976 than between VAR7178 and PCR6976, and a higher R^2 value for VAR7178 on PDRH-

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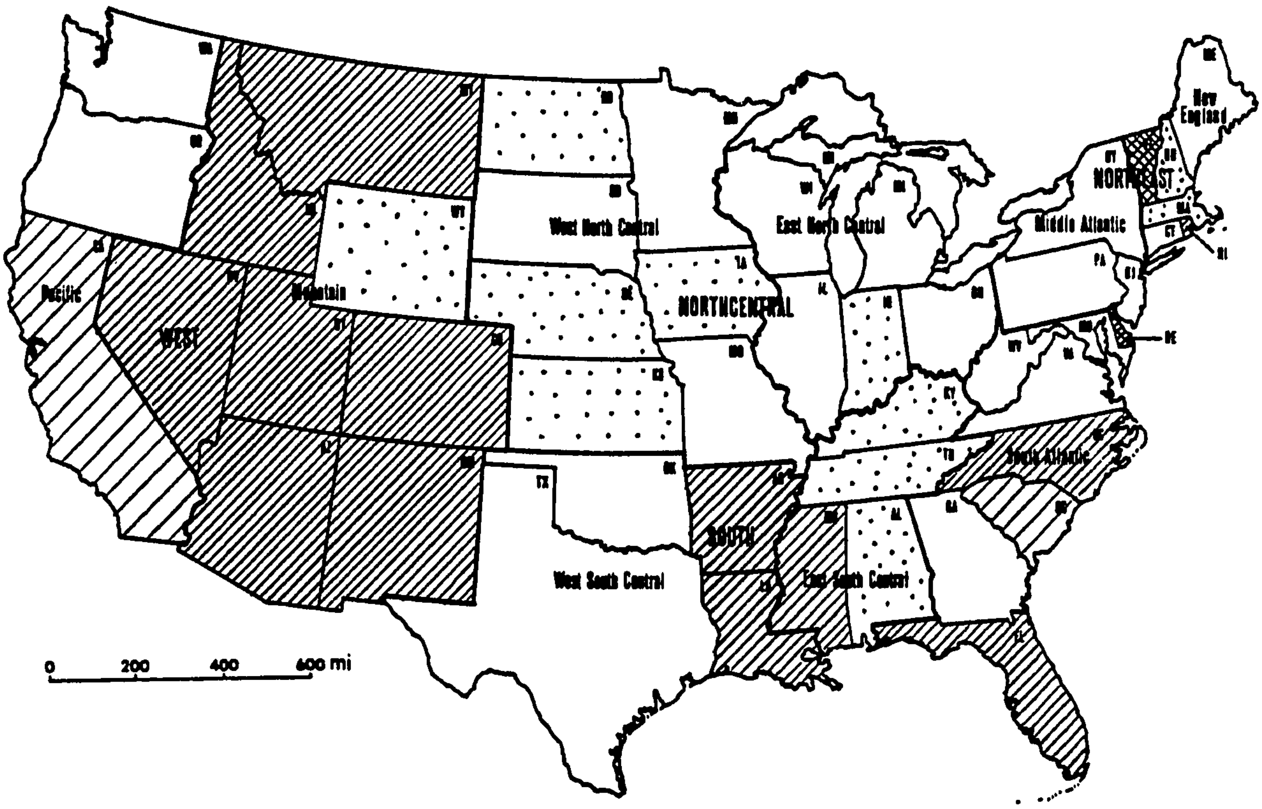
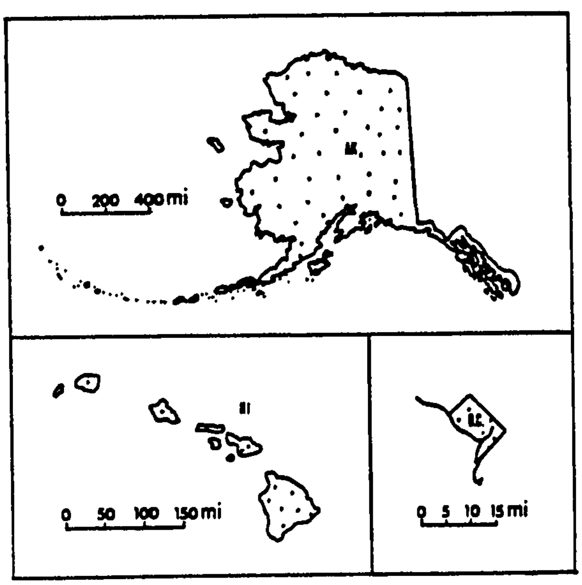
[8]Of the 27 periphery states which experienced positive growth in PDRL6976, five states including Alaska, Hawaii, North Dakota, Washington, D.C., and Wyoming experienced zero growth (Table 10).

MAP 8

PERCENTAGE CHANGE IN LOW
STATE PRODUCT TECHNOLOGY, 1969 - 1976 (PDRL6976)





Less than 0.0 %

0.0 % - 12.4 %

12.5 % - 24.9 %

25.0 % - 50.0 %

Over 50.0 %

Source: Table 10.

6976 (0.645) than for VAR7178 on PCR6976 (0.585), as shown in Tables 8 and 11. This suggests that, when considered separately, product technology has a greater influence on manufacturing output growth than does process technology. The more significant correlation between VAR7178 and PDRH6976 than between VAR7178 and PDRH7077 or PDRH7178 again indicates a two-year lag in the time of the peak impact of PDRH on VAR7178.

PDRH6976 also explains VAR7178 well in most states in the Manufacturing and Sun Belts. It overpredicts VAR7178 in five states (Kentucky, North Dakota, Nebraska, New Mexico, and Hawaii), but it underpredicts VAR7178 in nine states (New Hampshire, Oklahoma, Louisiana, South Dakota, Montana, Wyoming, Arizona, Nevada, and Oregon). Again, the growth rates of manufacturing output in large industrial states are well accounted for by this model.

Regression analyses of VAR7178 on PDRL for three consecutive seven-year periods (1969-1976, 1970-1977, and 1971-1978) indicate very weak positive correlations, as shown in Table 11. PDRL6976 explains only 6.2 percent of total variation in VAR7178. Due to the weak correlations between VAR7178 and PDRL, multiple regressions of VAR7178 on PDRH and PDRL are similar to those on PDRH alone. The coefficients of PDRL are all insignificant and most have a negative sign.

Dual Effects of Technological Change on State Manufacturing Output Growth

The analyses in the previous two sections have suggested the relatively greater importance of PCR over TPR in explaining the effects of the rate of change in state process technology on VAR7178, and also the dominance of PDRH over PDRL in the effect of the rate of change in state prod-

TABLE 11

THE GROWTH RATE OF STATE MANUFACTURING OUTPUT AND THE RATE OF CHANGE IN STATE PRODUCT TECHNOLOGY

Regression Equation and Model	Dependent Variable	Constant (a)	Coef-ficient (b)	Inde-pendent Variable	Coef-ficient (c)	Inde-pendent Variable	R^2
1 A	VAR7178	18.15	0.83* (9.43)	PDRH6976			0.645
2 A	VAR7178	34.19	0.97* (3.97)	PDRH7077			0.243
3 A	VAR7178	46.32	1.02* (4.47)	PDRH7178			0.290
1 B	VAR7178	26.20	0.14*** (1.80)	PDRL6976			0.062
2 B	VAR7178	28.18	0.01 (0.27)	PDRL7077			0.001
3 B	VAR7178	28.16	0.01 (0.42)	PDRL7178			0.004
1 C	PDRH6976	9.19	0.20** (2.86)	PDRL6976			0.143
2 C	PDRH6976	11.95	0.01 (0.70)	PDRL7077			0.010
3 C	PDRH6976	12.03	0.02 (0.80)	PDRL7178			0.013
4 C	PDRH7077	-6.30	0.01 (0.81)	PDRL7077			0.013
5 C	PDRH7077	-6.25	0.01 (0.90)	PDRL7178			0.016
6 C	PDRH7178	-18.05	0.02 (1.49)	PDRL7178			0.043
1 D	VAR7178	18.39	0.85* (8.95)	PDRH6976	-0.04 (0.69)	PDRL6976	0.648
2 D	VAR7178	32.25	0.92* (3.81)	PDRH7077	0.11 (1.56)	PDRL6976	0.280
3 D	VAR7178	44.01	0.96* (4.21)	PDRH7178	0.09 (1.33)	PDRL6976	0.315
4 D	VAR7178	18.28	0.83* (9.36)	PDRH6976	-0.01 (0.49)	PDRL7077	0.647
5 D	VAR7178	34.30	0.97* (3.92)	PDRH7077	-0.00 (0.15)	PDRL7077	0.243
6 D	VAR7178	47.05	1.04* (4.46)	PDRH7178	-0.01 (0.55)	PDRL7077	0.294
7 D	VAR7178	18.20	0.83* (9.33)	PDRH6976	-0.01 (0.37)	PDRL7178	0.646
8 D	VAR7178	34.19	0.97* (3.97)	PDRH7077	-0.00 (0.03)	PDRL7178	0.243
9 D	VAR7178	46.87	1.04* (4.43)	PDRH7178	-0.01 (0.44)	PDRL7178	0.293

Note: t-values are given in parentheses. * indicates significance at the 0.001 level, ** at the 0.01 level, and *** at the 0.10 level.

Sources: Regressions are of the form: (A) VAR7178 = a + b(PDRH), (B) VAR7178 = a + b(PDRL), (C) PDRH = a + b(PDRL), and (D) VAR7178 = a + b(PDRH) + c(PDRL).

uct technology on VAR7178. This section tests the hypothesis established in Chapter V by multiple regression analyses of VAR7178 on two sets of the rates of change in state process and product technologies including TPR, PDRH, and PDRL; and PCR, PDRH, and PDRL.[9]

Multiple regression analyses of VAR7178 on TPR, PDRH, and PDRL indicate significant effects of TPR and PDRH and insignificant effects of PDRL in the first nine regressions in Table 12. The effect of TPR on VAR7178 is the most significant for the 1971-1978 period (Equations 7A, 8A, and 9A), while that of PDRH is the most significant for the 1969-1976 period (Equations 1A, 4A, and 7A), which have been also indicated by the simple regression analyses performed in the previous two sections.

The R^2 is the highest (0.878) for VAR7178 on TPR7178, PDRH6976, and PDRL6976 (Equation 7A in Table 12). The R^2s are also consistently high (over 0.60) for four additional multiple regressions in which TPR7178 or PDRH6976 and PDRL6976 are employed as independent variables (Equations 1A, 4A, 8A, and 9A in Table 12). For other multiple regressions (Equations 2A, 3A, 5A, and 6A), the R^2s are substantially low due to much less significant effects of TPR, PDRH, and PDRL for other time periods. The two-year lag for patent related variables, therefore, has been consistent in this study as has the zero lag of total factor productivity variable.

Multiple regression analyses of VAR7178 on PCR, PDRH, and PDRL also indicate the most significant effects of PCR and/or PDRH for the 1969-1976

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[9]The two sets of independent variables were employed in multiple regression analyses in order to determine the relative importance of one set to the other in explaining the interstate variations in VAR7178. Also, PDRL was included in each set of independent variables, despite its weak correlation with VAR7178, because it represents a part of the change in state product technology.

TABLE 12

DUAL EFFECTS OF THE RATES OF CHANGE IN STATE PROCESS AND PRODUCT TECHNOLOGIES ON THE GROWTH RATE OF STATE MANUFACTURING OUTPUT FOR THE 1971-1978 PERIOD

Regression Equation and Model	Constant (a)	Coef- ficient (b)	Inde- pendent Variable	Coef- ficient (c)	Inde- pendent Variable	Coef- ficient (d)	Inde- pendent Variable	R^2
1 A	15.11	0.37** (2.76)	TPR6976	0.84* (9.45)	PDRH6976	-0.01 (0.22)	PDRL6976	0.697
2 A	31.69	0.30 (1.49)	TPR6976	0.96 (3.97)	PDRH7077	0.00 (0.00)	PDRL7077	0.276
3 A	44.08	0.33*** (1.69)	TPR6976	1.04* (4.51)	PDRH7178	-0.01 (0.28)	PDRL7178	0.333
4 A	8.94	0.73* (4.91)	TPR7077	0.77* (9.66)	PDRH6976	-0.00 (0.10)	PDRL6976	0.767
5 A	20.94	0.93* (4.12)	TPR7077	0.91* (4.23)	PDRH7077	0.01 (0.35)	PDRL7077	0.444
6 A	32.98	0.91* (4.29)	TPR7077	0.97* (4.96)	PDRH7178	0.00 (0.08)	PDRL7178	0.487
7 A	5.91	1.00* (9.41)	TPR7178	0.68* (11.53)	PDRH6976	-0.03 (0.93)	PDRL6976	0.878
8 A	14.59	1.29* (7.59)	TPR7178	0.80* (4.69)	PDRH7077	-0.00 (0.19)	PDRL7077	0.660
9 A	23.87	1.20* (6.55)	TPR7178	0.72* (4.04)	PDRH7178	-0.01 (0.35)	PDRL7178	0.630
1 B	18.35	0.11 (0.24)	PCR6976	0.75*** (1.76)	PDRH6976	-0.05 (0.64)	PDRL6976	0.649
2 B	21.77	0.67* (6.81)	PCR6976	0.38*** (1.92)	PDRH7077	-0.01 (0.88)	PDRL7077	0.619
3 B	28.88	0.64* (6.85)	PCR6976	0.51*** (2.79)	PDRH7178	-0.02 (1.05)	PDRL7178	0.646
4 B	19.95	0.22 (1.22)	PCR7077	0.80* (7.63)	PDRH6976	-0.06 (1.15)	PDRL6976	0.659
5 B	32.07	1.24*** (2.61)	PCR7077	-0.10 (0.21)	PDRH7077	-0.06*** (2.18)	PDRL7077	0.339
6 B	38.86	0.77*** (2.01)	PCR7077	0.46 (1.25)	PDRH7178	-0.05*** (1.72)	PDRL7178	0.349
7 B	23.84	0.29*** (1.83)	PCR7178	0.77* (7.63)	PDRH6976	-0.07 (1.38)	PDRL6976	0.672
8 B	48.98	1.54* (3.55)	PCR7178	-0.43 (0.95)	PDRH7077	-0.08** (2.98)	PDRL7077	0.403
9 B	44.80	1.41** (2.74)	PCR7178	-0.23 (0.45)	PDRH7178	-0.08*** (2.52)	PDRL7178	0.390

Note: t-values are given in parentheses. * indicates significance at the 0.001 level, ** at the 0.01 level, and *** at the 0.10 level.

Sources: Multiple regressions are of the form: (A) VAR7178 = a + b(TPR) + c(PDRH) + d(PDRL), and (B) VAR7178 = a + b(PCR) + c(PDRH) + d(PDRL).

period and less significant or insignificant effects of PCR or PDRL for the other two periods (Equations 1B through 9B in Table 12). The results correspond to the earlier findings on the two-year lag in the time of the peak impact of PCR or PDRH on VAR7178. In addition, the analyses indicate the weak effects of PDRL on VAR7178 which are significant and negative for the 1970-1977 and 1971-1978 periods (Equations 5B, 6B, 8B, and 9B in Table 12).

The R^2s are also consistently over 0.60 in the multiple regressions (Equations 1B, 2B, 3B, 4B, and 7B in Table 12) where PCR6976 or PDRH6976 have strong effects and PDRL has no significant effects on VAR7178. On the contrary, the R^2s are substantially low in the remaining four multiple regressions (Equations 5B, 6B, 8B, and 9B in Table 12) due to less significant effects of PCR and/or PDRH and the significant negative effects of PDRL on VAR7178. Despite the most significant individual effects of PCR6976 and PDRH6976 on VAR7178, the R^2 is the highest for VAR7178 on PCR7178, PDRH6976, and PDRL6976 rather than for VAR7178 on PCR6976, PDRH6976, and PDRL6976, due to a much more significant correlation between PCR6976 and PDRH6976 than between PCR7178 and PDRH6976, as shown in Table 9.

The two multiple regressions which provide the highest R^2 values (Equations 7A and 7B in Table 12) clearly indicate that the growth rate of state manufacturing output (VAR) increased during the 1971-1978 period with the rate of change in state process technology for the same period as measured by TPR7178 or PCR7178 and also with the rate of change in state product technology as measured by PDRH6976 which lags two years behind TPR7178 or PCR7178.

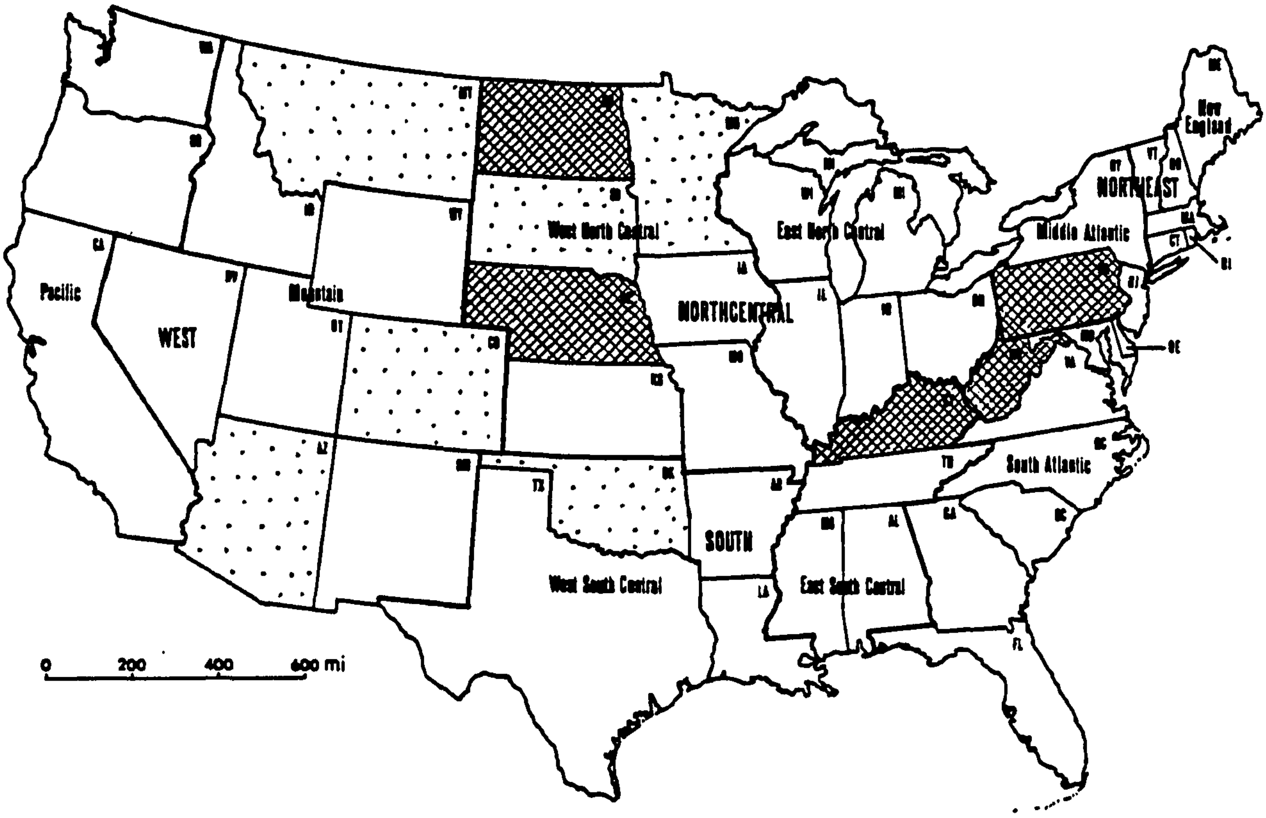
The independent variables in Equations 7A and 7B in Table 12 explain most of the interstate variations in VAR7178, TPR7178, PDRH6976, and PDRL-

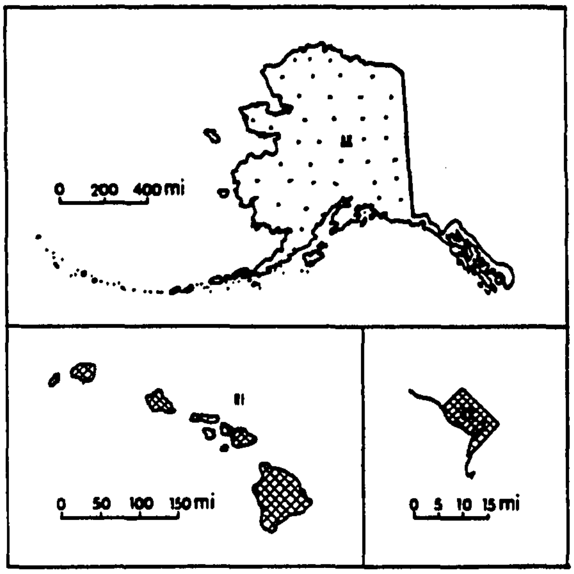
6976 overpredict VAR7178 in seven states (Pennsylvania, West Virginia, Kentucky, North Dakota, Nebraska, Hawaii, and Washington, D.C.) and they underpredict VAR7178 in another seven states (Minnesota, Alaska, Arizona, Montana, Colorado, South Dakota, and Oklahoma), as shown in Map 9. On the other hand, PCR7178, PDRH6976, and PDRL6976 overpredict VAR7178 in five states (Kentucky, Hawaii, Nebraska, North Dakota, and Kansas) and underpredict it in seven states (New Hampshire, Louisiana, Mississippi, Oregon, Nevada, Montana, and Wyoming), as shown in Map 10. These residual analyses indicate that TPR7178, PDRH6976, and PDRL6976 explain better the interstate variations in VAR7178 in the Manufacturing Belt, the West North Central Region, and the West than in the Sun Belt, while PCR7178, PDRH6976, and PDRL6976 explain them better in the Manufacturing and Sun Belts than in the West and the West North Central Region. The analyses also indicate the importance of the four independent variables (TPR7178, PCR7178, PDRH6976, and PDRL6976) in explaining the shifting core-periphery relationships which the analysis of the interstate variations in VAR7178 has presented previously in this chapter.

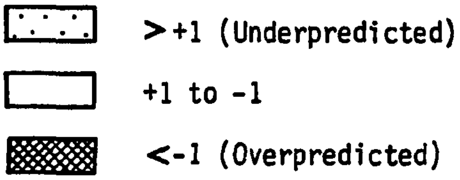
The evidence presented in this chapter confirm the hypothesis which holds that the interstate variations in the growth rate of state manufacturing output are determined by the rates of change in state process and product technologies. It must be noted, however, that the evidence is consistent with the hypothesis for the variables and the periods selected for the test of the hypothesis. Therefore, it is suggested that the interstate variations in the growth rate of state manufacturing output for the 1971-1978 period are determined by the rate of change in state process technology for the same period as measured by either TPR7178 or PCR7178 and by the rate of change in state product technology for the 1969-1976 period as meas-

MAP 9

STANDARDIZED RESIDUALS FOR VAR7178
ON TPR7178, PDRH6976, AND PDRL6976



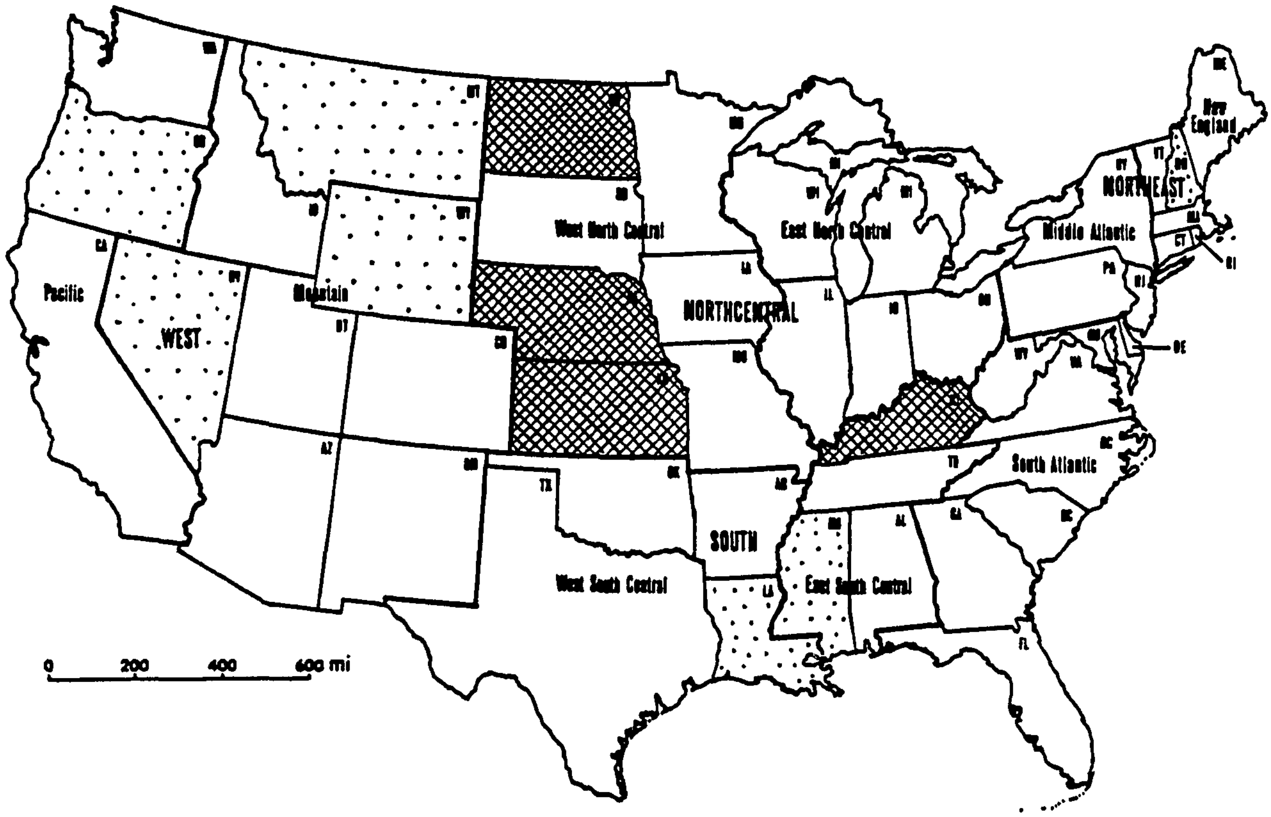


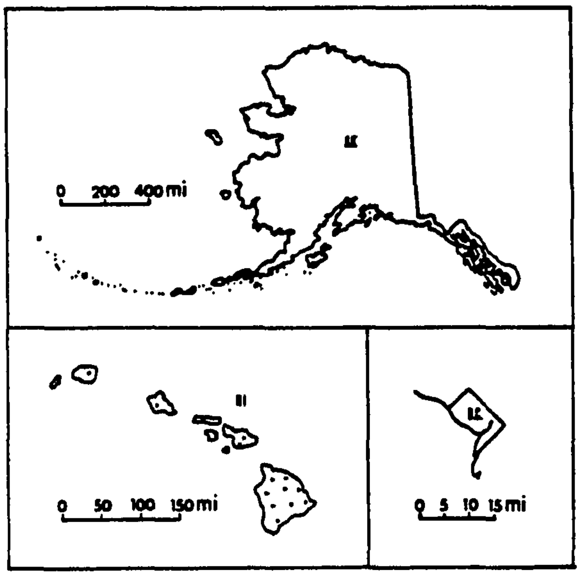


Source: Equation 7A in Table 12.

MAP 10

STANDARDIZED RESIDUALS FOR VAR7178
ON PCR7178, PDRH6976, AND PDRL6976





>+1 (Underpredicted)

+1 to -1

<-1 (Overpredicted)

Source: Equation 7B in Table 12.

ured by PDRH6976. However, this two-year lag in the time of the peak impact of PDRH on VAR7178 is not conclusive. The lag may be more than two years, although it is difficult to confirm due to the lack of employment data by state and by industry group which are required to estimate PDRH for the periods preceding the 1969-1976 period.

CHAPTER VII

CONCLUSION

This study has been concerned primarily with testing the hypothesis that interstate variations in the growth rate of state manufacturing output are determined by the rates of change in state process and product technologies. In addition, this study has determined 1) the individual relationships between the growth rate of state manufacturing output and the rates of change in state process technology and in state product technology, 2) the regional patterns of the interstate variations in each of the four variables for the rates of change in state process and product technologies, and 3) the regional patterns in the distribution of state patenting activity and its intensity.

Summary of Findings

The analyses of the combined effects of the rates of change in state process and product technologies on the growth rate of manufacturing output generally support the hypothesis. The effects were the most significant for the period for which both the growth rate of state manufacturing output and the rate of change in state process technology were measured and also for the period which lags two years behind the one for the growth rate of state manufacturing output. The rates of change in state process and product technologies generally explained substantial portions of interstate variations in the growth rate of state manufacturing output. This finding essentially indicates a shifting core-periphery relationship away from the U.S. Northeast and toward the South and West.

Individually, the rate of change in state product technology as measured by the rate of change in the number of patents utilized as high and intermediate state product technology (PDRH) was found to be more important than the rate of change in state process technology as measured by the rate of change in the number of patents utilized as state process technology (PCR) or by the rate of change in state total factor productivity (TPR) in explaining the interstate variations in the growth rate of state manufacturing output (VAR). The rate of change in the number of patents utilized as low state product technology (PDRL) was seen to be an insignificant variable.

Of the four measures, only the rate of change in state total factor productivity had its peak impact on the growth rate of state manufacturing output for the same period. The other three measures had their peak impacts for the period lagging two years behind the period for the growth rate of state manufacturing output. The analyses of the interstate variations in each of the four measures for the periods for which each had its peak impact reinforced the generally observed pattern of shifting core-periphery relationships. The patterns, however, were more distinctive in the interstate variations of the rates of change in the number of patents utilized as state process technology (PCR) and in the number of patents utilized as high and intermediate state product technology (PDRH) than in the interstate variations of the rates of change in state total factor productivity

(TPR) and in the number of patents utilized as low state product technology (PDRL). Due to such relationships between VAR and the four measures, the combined effects of PCR and TPR on VAR were generally much more significant than those of PDRH and PDRL. Also, the combined effects of the two sets of measures were the most significant for the periods for which each measure individually had its peak impact on VAR.

The analyses of regional patterns in the distribution of both state patenting activity and its intensity also indicated shifting core-periphery relationships. The shifts in the relationship, however, were biased toward the South in the intensity of state patenting activity. State patenting activity was found to be strongly correlated with the two R&D measures: the number of R&D labs and the number of employees with central administrative offices. However, the intensity of state patenting activity was less strongly correlated with the two R&D measures normalized by population.

Implications and Suggestions for Future Research

The role of technological change has been a dominant issue in the study of regional economic growth, since Perroux (1955) developed the concept of growth pole. This study was an attempt to extend the study of regional economic growth via some specific operational variables available for technological change and economic growth at the state level in the United States.

The evidence presented in this study strongly supports Thomas' (1975) concept of dual roles of technological change in regional economic growth, despite the limitations of raw data as well as the use of the growth rate of state manufacturing output as the measure of regional economic growth. The findings in this study as summarized above have several significant implications for the study of technological change and regional economic growth.

First, the fact that the combined effects of the rates of change in state process and product technologies on the growth rate of state manufacturing output are more significant than their individual effects confirms the existence of dual roles of technological change, which had been conceptualized but not empirically demonstrated.

Second, a highly significant correlation between the growth rate of state manufacturing output and the rate of change in high and intermediate state product technology (PDRH) suggests the importance of the change in product technology for manufacturing growth, which has largely been neglected by growth pole theorists as well as economists. It also indicates the importance of the change in high technology products for state manufacturing growth which reinforces the popular notion that the change in high technology is vital to state economic growth. For example, state economic development activity could identify industries that would complement existing state industry, but at the same time, tend toward high technology sectors. However, if most industrial linkages are with firms in other states, the local economic benefit will be greatly reduced.

Third, a stronger correlation between the growth rate of state manufacturing output (VAR) and the rate of change in the number of patents utilized as state process technology (PCR) than between VAR and the rate of change in state total factor productivity (TPR) implies that the rate of change in state process technology can be better measured by PCR than by the traditional TPR which has been criticized as a poor measure of technological change (Mansfield, 1968; Gold, 1977). The patent utilization variable

(PCR) constructed here does appear to be somewhat superior to the conventional productivity-based measure (TPR).

Fourth, the difference in the lag between the peak impact of the rate of change in state process technology and that of the rate of change in state product technology is regarded as the time required for the transformation of product technology to process technology (Schmookler, 1966; Thomas, 1981). The lag may be longer than two years, but it appears to take at least two years for patented inventions to have a noticeable impact on state manufacturing output.

Fifth, the significant predictive power of the rate of change in the number of patents utilized as high and intermediate state product technology (PDRH) and in the number of patents utilized as state process technology (PCR) suggests that the number of utilized patents estimated on the basis of R&D utilization rates (Scherer, 1982b) provides an adequate measure of the analysis of interstate or interregional variations of technological change.

Sixth, the regional shifts in the growth rate of state manufacturing output, in the four measures of the rate of technological change at the state level, and in state patenting activity and its intensity provide additional dimensions to the empirical study of the shifting core-periphery relationships in the United States. Study of these shifts had been confined primarily to the analysis of shifts in manufacturing employment.

Finally, the strong correlations between state patenting activity and two R&D measures (the number of R&D labs and the number of employees with central administrative offices) and also between the intensity of state patenting activity and the two measures normalized by population indicate that patents are an important measure at the state level as well as at the city, national, and international levels (Feller, 1971; Schmookler, 1966; Pavitt and Soete, 1980).

In conclusion, Thomas' (1975) concept of dual roles of technological change is concerned with long-term effects of technological change on regional economic growth and on regional economic structure. Due to the limitations of data, this study has analyzed the combined effects of technological change on state manufacturing output growth for a short period of seven years only. The two components of technological change (the changes in process and product technologies) are each closely related to state manufacturing output growth, within the limitations of the variables and time periods in this study. However, the short time period for state manufacturing output growth and the single year of data for patent utilization rates made this study somewhat inconclusive as support for the entire concept of dual roles of technological change in regional economic growth.

The future study of technological change and regional economic growth should be concerned not only with the dual effects of regional technological change on the growth of entire sectors of regional economy for a much longer period, such as twenty or thirty years, but also with the changes in the input-output linkages of regional industries. In addition, the development of new measures of regional process and product technologies besides the number of utilized patents would substantially contribute to further progress of the study of technological change and regional economic growth.

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